MAINTENANCE OF ELECTRONIC PROCESS CONTROL SYSTEMS UNDER DORMANT CONDITIONS

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Maintenance of Electronic Process
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FINAL REPORT

MAINTENANCE OF ELECTRONIC PROCESS CONTROL SYSTEMS UNDER DORMANT CONDITIONS

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TABLE OF CONTENTS

Page

I INTRODUCTION 1
  A. Purpose 1
  B. Scope 2
  C. Methodology 3

II EXECUTIVE SUMMARY 7
  A. Conclusions 8
    1. Trends In Electronic Process Control Systems 8
    2. Trends In Computer Industry Maintenance Service 9
    3. U.S. Army Ammunition Plants' EPCS Status 10
    4. Long-Term (20 Year) Planning 11
    5. Commercial Dormancy Experience 11
  B. Recommendations 13
    1. ARRCOM System Development Center 13
    2. Procurement Process 13
    3. Standardization 14
    4. Dormancy Testing 15
    5. System Layaway 15
    6. Third-Party Maintenance Companies 15

III INDUSTRY TRENDS 17
  A. Introduction To Process Control 17
    1. Description 17
    2. Brief History And Trends 19
    3. Market Size 25
  B. Maintenance Trends In The Computer Industry 27
    1. Design For Maintainability 29
      a. Equipment Design For Reliability And Serviceability 29
      b. Testing 31
    2. Personnel Trends 32
      a. Local Field Service Technician (LFST) 33
      b. Local Field Support Specialist (LFSS) 33
      c. Central Site Support Specialists (CSSS) 34
    3. New Maintenance Techniques 34
      a. Remote Diagnostics 34
      b. Self-Maintenance Procedures 43

Page

        c. Depot Maintenance 44
        d. System Support Centers 45
    4. Maintenance Cost Trends 47
    5. Maintenance Contract Trends 52
    6. Third-Party Maintenance (TPM) 53
    7. Training Trends 56
        a. Lecture/Lab 57
            i. Advantages 57
            ii. Disadvantages 57
            iii. Costs 58
        b. Self-Study Method 58
            i. Advantages 59
            ii. Disadvantages 59
            iii. Costs 59
        c. Video Courses 60
            i. Advantages 61
            ii. Disadvantages 62
            iii. Costs 62
        d. Computer Based Instruction 62
            i. Advantages 63
            ii. Disadvantages 63
            iii. Costs 64
    8. Escalation Procedures 65
    9. Spare Parts 66

IV AMMUNITION PLANT EPCS STATUS 69
A. General Information 69
B. Joliet Army Ammunition Plant 69
    1. Plant Description 69
    2. Electronic Process Control System Description 71
    3. Operating Experience 74
    4. Layaway And Reactivation 75
    5. Spare Parts Management 77
    6. Personnel Skills Program 78
    7. Future Plans 79
C. Lake City Army Ammunition Plant 80
    1. Plant Description 80
    2. Electronic Process Control System Description 81
        a. Case, Bullet, Load and Assemble Submodules 81
        b. Primer Insert Submodules 87
        c. Automated Material Handling System 87
        d. Cartridge Case Measurement And Eject System 89
        e. Management Information System 89
    3. Operating Experience 90
    4. Layaway And Reactivation 92
    5. Spare Parts Management 93
    6. Personnel Skills Program 94
    7. Future Plans 94
    8. Miscellaneous 95

INPU

Page

D. Lone Star Army Ammunition Plant 95
  1. Plant Description 95
  2. Electronic Process Control System Description 97
  3. Operating Experience 101
  4. Layaway And Reactivation 101
  5. Spare Parts Management 103
  6. Personnel Skills Program 103
  7. Future Plans 104
  8. Miscellaneous 105
E. Louisiana Army Ammunition Plant 105
  1. Plant Description 105
  2. Electronic Process Control System Description 106
  3. Operating Experience 108
  4. Layaway And Reactivation 109
  5. Spare Parts Management 110
  6. Personnel Skills Program 111
  7. Future Plans 112
  8. Miscellaneous 112
F. Mississippi Army Ammunition Plant 112
  1. Plant Description 112
  2. Electronic Process Control System Description 113
  3. Operating Experience 115
  4. Layaway And Reactivation 115
  5. Spare Parts Management 116
  6. Personnel Skills Program 117
  7. Future Plans 117
  8. Miscellaneous 117
G. Radford Army Ammunition Plant 118
  1. Plant Description 118
  2. Electronic Process Control System Description 119
  3. Operating Experience 124
  4. Layaway And Reactivation 125
  5. Spare Parts Management 126
  6. Personnel Skills Program 127
  7. Future Plans 128
  8. Miscellaneous 129
H. Volunteer Army Ammunition Plant 129
  1. Plant Description 129
  2. Electronic Process Control System Description 130
  3. Operating Experience 132
  4. Layaway And Reactivation 133
  5. Spare Parts Management 134
  6. Personnel Skills Program 135
  7. Future Plans 135
  8. Miscellaneous 136

V MAINTENANCE METHODOLOGIES 137
  A. Introduction 137

Page

B. Vendor Analysis 138
  1. System Vendors 138
    a. Status Of Current Systems 138
    b. Support Plan 143
    c. Dormancy 152
    d. Maintenance Philosophy 158
  2. Maintenance Service Vendors 161
    a. General Climate 161
    b. Layaway Approaches 171
  3. Other Vendors 172
C. User Analysis 176
  1. Systems 176
  2. Software 179
  3. System Backup 180
  4. Support 181
  5. Reliability 182
  6. Maintainability 183
  7. Personnel 185
  8. Spare Parts Management 186
  9. Dormancy Experiences 188
    a. User 1 188
    b. User 2 189
    c. User 3 189
    d. User 4 189
    e. User 5 189
    f. User 6 190

VI SPARE PARTS MANAGEMENT 191

VII PERSONNEL 203
A. Vendor Field Service Organizations 203
B. Training 212
C. Personnel Tracking 215
D. Professional Services Companies 216
E. Third-Party Maintenance Companies 217

VIII CONCLUSIONS 219
A. Ammunition Plants 221
B. Vendors 226
C. Users 227

IX RECOMMENDATIONS 229
A. General 229
  1. Minimize The Number Of Units Involved 230
  2. Increase The Army's Supervisory Role 232
  3. Institute Long-Term Planning 232
B. System Procurement Recommendations 235
  1. Standardize 235
  2. Seek Vendors Who Can Demonstrate Long-Term Commitments 235
  3. Specify Requirements 236

Page

C. Maintenance Procurement Recommendations 238
    1. Spares 238
    2. Personnel Training 240
    3. Training And Retraining 241
    4. Escalation Procedures 241
    5. Reliability Improvement Program 241
    6. Choice Of Maintenance Provider 242
    7. Lines Of Communication 243
D. Layaway And Reactivation Recommendations 244
    1. Layaway Recommendations 244
    2. Reactivation Recommendations 246
E. Existing Facilities 248
F. PCP-88 Systems Recommendations 249

APPENDIX A: SOURCES AND BIBLIOGRAPHY 255

APPENDIX B: DEFINITIONS 265

APPENDIX C: COMPUTER PROFESSIONAL SERVICES COMPANIES 271
    A. List I 271
    B. List II 273

APPENDIX D: COMPUTER MAINTENANCE SERVICES COMPANIES 281

APPENDIX E: ZERUST VAPOR CAPSULE EVALUATION 295

APPENDIX F: GAO PROVISIONAL CHECKLIST FOR SOFTWARE DEVELOPMENT CONTRACTING 317
    A. Phase: Pre-Contract 317
    B. Phase: Contracting 320
    C. Phase: Proposal Evaluation 325
    D. Phase: Performance Period 326
    E. Phase: Post-Contract 330

APPENDIX G: INTERVIEW PROGRAM 333

APPENDIX H: INTERVIEW GUIDES 335
    Ammunition Plant Site Discussion Outline 335
    Electronic Process Control System User Discussion Guide 357
    Electronic Process Control System Vendor Discussion Guide 375

MAINTENANCE OF ELECTRONIC PROCESS CONTROL SYSTEMS UNDER DORMANT CONDITIONS

LIST OF EXHIBITS

			Page
I	-1	Nine Federal Agency Software Development Contracts Totaling $6.8 Million: Where The Money Went	4
III	-1	Hierarchical Organization Of An Advanced Process Control System	22
	-2	Evolution Of Direct Digital Control Systems	24
	-3	Projected Total Spending For Process Control Equipment, 1970-1990	26
	-4	Process Control Computer System Forecast	28
	-5	Shift In Distribution Of Skill Levels Of Field Service Personnel	35
	-6	DEC Remote Diagnostic Center	39
	-7	DEC System Operation And Procedure	41
	-8	Typical Support Center Hierarchy	48
	-9	Planned Response Time To Maintenance Calls With/Without Support Centers	49
	-10	Total User System Expenditures Over A Seven-Year Life Cycle	50
IV	-1	U.S. Army Armament Materiel Readiness Command	70
	-2	Simplified Block Diagram Of Foxboro PCP-88 Electronic Process Control System As Used At Joliet And Volunteer Army Ammunition Plants	73
	-3	Contractors Involved In The Development Of The Automated Production Facility At LCAAP	82
	-4	Simplified Factory Automation Layout At Lake City Army Ammunition Plant	83
	-5	5.56mm Case Sub-Module	84
	-6	Bullet Sub-Module "A" (Ball)	85
	-7	Load And Assemble Sub-Module	86
	-8	5.56mm Primer Insert Sub-Module	88
	-9	Simplified E-Line Computer Control System At Lone Star Army Ammunition Plant	98
	-10	Planned Layaway And Reactivation Cycles At LSAAP	102
	-11	LAAP Y-Line Electronic Control Systems	107

Page

-12 Process Sampling Points - CASBL Manufacturing Area 120
-13 CASBL Dual Computer System 121

V -1 Types Of Vendors Interviewed 139
-2 Test Interval Analysis 154
-3 Failure Modes And Effects Analysis (FMEA) 155
-4 Profit Center Or Cost Center Organization Of Responding Vendors 163
-5 Vendor Ratings Of Problems Related To Field Service 164
-6 Vendor Responses To Equipment Availability 165
-7 Vendor Responses On Impact Of Factors Relevant To Maintenance Techniques 170
-8 ZERUST® Anticorrosive Plastic Bag 175
-9 Typical Users Interviewed 177
-10 Process Control Systems At Users' Sites 178

VII -1 Expected Increase In Field Service Organization Size, 1980-1982-1984 204
-2 Comparison Of FE New Hires And Separations - 1979 205
-3 Ratings Of Primary Sources Of New FS Personnel 208
-4 Comparison Of Average Salaries 210
-5 Effect Of Elapsed Time Between Calls On Retention Of Learning 214

VIII -1 Communications - A Key Factor 225

IX -1 ARRCOM And Contractor Responsibilities Alternative Scenarios 231
-2 Suggested EPC System Usage Alternatives 239

I INTRODUCTION

I INTRODUCTION

A. PURPOSE

- This study was conducted at the behest of the U.S. Army Armament Research and Development Command (ARRADCOM), Dover, New Jersey, for the purposes of:

  - Projecting future trends in electronic process control (EPC) systems development and relating those trends to the reliability and maintenance of such systems during long-term storage.

  - Determining what private industrial experiences relating to the long-term storage of electronic systems could be applied to the Army ammunition plant problem.

  - Outlining a framework for the maintenance of electronic process control systems in long-term storage.

  - Determining the status of layaway plans at selected Army ammunition plants.

- The U.S. Army Armament Materiel Command (ARRCOM) manages the Army's munitions production base. ARRCOM's headquarters are in Rock Island, Illinois.

B. SCOPE

- The information gathered and analyzed is directed toward procuring new electronic process control systems, upgrading existing systems, and providing a guide for laying away all systems.

- Trends in maintenance methodologies are presented with an assessment of their impact on the dormant state problem.

- Maintenance personnel sources and training are discussed as they relate to the operating contractors' role.

- Eight appendices are included in support of this study:

    - Appendix A lists the outside sources for this report and also includes a bibliography.

    - Appendix B contains the definition of terms in the process control field.

    - Appendix C lists professional services companies in the computer field specializing in manufacturing. These companies provide consulting, software packages, training, facilities management, and programming services.

    - Appendix D lists the larger computer maintenance service companies.

    - Appendix E includes tests of a new product discovered during the research for this study, which is effective in inhibiting corrosion in factory areas with high humidity and corrosion atmospheres.

    - Appendix F is a set of GAO guidelines for entering into software contracts. These guidelines, which refer to government only, should be useful for any systems contract. In general, software produced for federal agencies has not been very useful as it was originally delivered to the government, as shown in Exhibit I-1. These guidelines are suggested to increase the return on the software investment. (Note: There are no comparable statistics for the private sector nor any GAO follow-up study on the procurement results after this initial study.)

- Appendix G lists the type of companies interviewed for this study and the number of telephone and on-site interviews completed in the study.

- Appendix H contains the interview guides used for the study.

C. METHODOLOGY

- Data gathering was accomplished by 29 interviews with vendors and users of electronic process control systems.

    - Users were engineers who were knowledgeable in EPC systems and vendors of electronic process control systems.

    - Forty percent of the interviews were done on-site and 60% were by telephone.

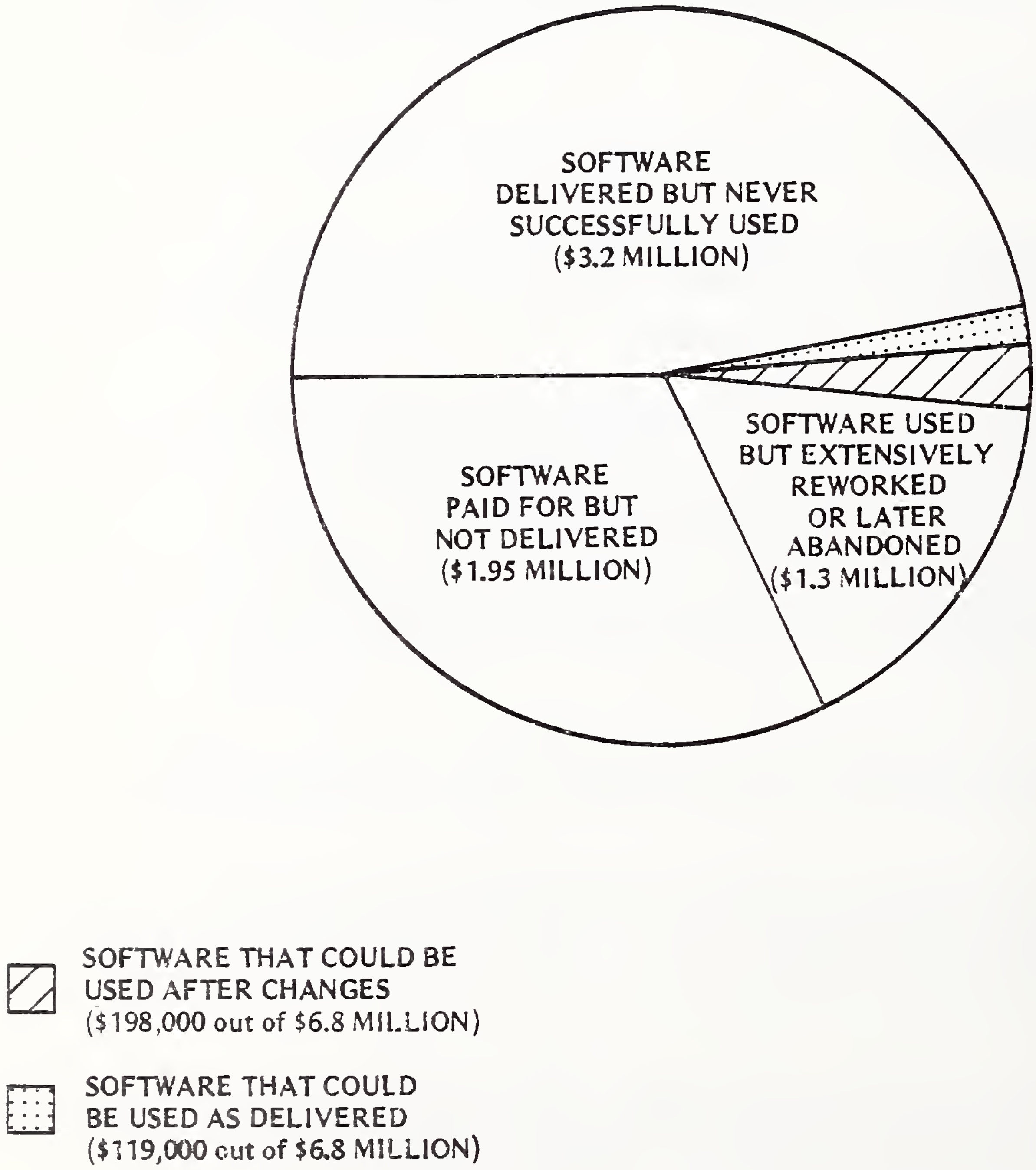
- Seven Army ammunition plants were visited for at least one day, and were reported on.

    - A visit was made to the Joliet Army Ammunition Plant in conjunction with a reactivation cycle.

- An extensive literature search was conducted over several commercial data bases for literature pertaining to dormancy of high-technology equipment, but little available data was directly applicable to the immediate problem.

EXHIBIT I-1

NINE FEDERAL AGENCY SOFTWARE DEVELOPMENT CONTRACTS TOTALING $6.8 MILLION: WHERE THE MONEY WENT



SOURCE: GAO REPORT: FGMSD-80-4
DATED: NOVEMBER 9, 1979

  - Included in the search were DIALOGUE and NTIS.

- Pertinent material was located in previous INPUT studies which will be referenced throughout the study.

II EXECUTIVE SUMMARY

II EXECUTIVE SUMMARY

- This report outlines the trends in electronic process control (EPC) systems as they impact U.S. Army ammunition plants.
  - The technical advances in microcircuitry and microprocessors, for example, have a significant impact on planning for periods when the plants are dormant.
  - This impact will result in replacing centralized control with decentralized control at the plant and workstation.
- The report further examines the trends in maintenance service which will profoundly affect the Army's planning for dormant installations.
  - These trends will have an impact which will be felt by the Army in planning for and supplying spare parts, obtaining technical support, and training.
- With these trends as a background, the following report by INPUT will detail the present status of U.S. Army ammunition plants.
  - Differences between these plants and the typical manufacturing plant will be explored.

- The planning process for EPC systems will be discussed with specific recommendations.

  - Finally, commercial dormancy experience will be discussed to determine if the Army can benefit from the experience in the commercial sector.

A. CONCLUSIONS

1. TRENDS IN ELECTRONIC PROCESS CONTROL SYSTEMS

- Electronic process control systems have completed an evolutionary cycle.

  - Initially, process control was located at the site of the equipment under the direction of individuals and instruments.

  - Large-scale computers, in the 1960s, brought change as control became centralized at some remote control station.

  - The advent of microprocessors and inexpensive computers, in the 1970s, has resulted in decision-making and control being, once again, decentralized to the field.

- The key factor, inexpensive intelligence and control devices, is greatly changing the technology, planning, and approach to EPC systems.

  - The distribution of intelligence and control devices to the workstation will decrease the need for redundant hardware because individual failures do not disrupt the total process.

  - The main CPU will serve less as the key component of the control system as controls will be located at the machine site.

  - A single failure will not have the magnitude of effect in this new environment.

  - Systems will be easier to maintain because the individual system's elements will be increasingly more standardized and more easily replaceable.

2. TRENDS IN COMPUTER INDUSTRY MAINTENANCE SERVICE

- All costs of providing maintenance service are increasing, while the supply of skilled personnel is decreasing.

  - EPC vendors are seeking to provide quality service by concentrating their personnel in a central or regional location and having the customer come to this service center in one fashion or another.

    - This information came forth clearly from the interviews conducted in this study.

  - Providing service from this service center via communication lines and having the user participate in the service process is a viable means of increasing the field engineers' productivity and of satisfying the customer's requirements.

  - Using the service center, called a remote diagnostic center, as the testing center, EPC systems at ammunition plants can be reactivated and tested, and, as a result, skilled computer personnel will operate the system from this remote diagnostic center.

- The increasing use of self-diagnostic hardware and software will help service personnel to detect defective components before a bad component can shut down a system.

3. U.S. ARMY AMMUNITION PLANTS' EPCS STATUS

- The operating contractors of the ammunition plants visited by INPUT were aware of many of the implications of keeping electronic systems dormant for long periods, but few have laid out comprehensive plans for addressing the effects of dormancy.

    - The impetus provided by ARRADCOM's direction and funding has served to pinpoint the major problems and is continuing to assist in finding solutions, but these problems are not of the highest priority for the operating contractors.

        - It should be realized, however, that the contractors are responsible for the entire plant, and the automated lines are only a portion of the plant's total production capability.

    - On occasion the contractors gave the impression that the automated line just complicated the maintenance and mobilization problems.

- U.S. Army ammunition plants are different from commercial manufacturing complexes. Army ammunition plants do not run at full production all of the time as do commercial plants. Ammunition plants operate at full production, at partial production, or are dormant during their existence.

    - Currently, INPUT concludes, these differences are not always considered in the design of the plant which is a problem being addressed by ARRADCOM in its study, MMT 4322.

    - It appears to INPUT that the automated lines, even though different, are designed in the same manner as industrial production lines - to operate 24 hours per day, 365 days per year; the ARRADCOM study should shed more light on this potential problem.

4. LONG-TERM (20 YEAR) PLANNING

- Planning for a five-year period seems to be too short because it takes longer to design, build, install, and test a complex EPC system.

    - EPC systems for Army ammunition plants are designed for 20 years and, therefore, planning should include the lifetime of the system in order to maximize the return on the investment.

- Planning should include all the plants as well as the longevity (20 years) of the plants.

    - There has not been a consistent attempt to obtain leverage with any particular manufacturer and vendors vary from plant to plant just as systems vary. System replication was found, however, in at least two cases, the Joliet Army Ammunition Plant and the Volunteer Army Ammunition Plant.

- The multiplicity of contractors involved in each EPC system spreads the responsibility so that conflicts and crossed communications can occur and can lead to a lengthy design-to-operation cycle.

    - By the time some systems become operational, the hardware is obsolete.

    - If the line requires six years from design to implementation the computer could be phased out by the manufacturer.

5. COMMERCIAL DORMANCY EXPERIENCE

- Some of the commercial users of EPC systems, who were interviewed, experienced varying periods of dormancy but none experienced the 15 to 20 years facing the operating contractors at the ammunition plants.

  - Two years was the longest period for which a commercial system located among the respondents was dormant. The system was stored in a heated warehouse and was covered with plastic bags. Reactivation problems were minimal.

    . There were no indications of humidity problems either.

  - Other users had worse reactivation experiences with less dormant storage. Poor or sloppy layaway procedures and conditions were blamed for the problems, rather than the length of time or the equipment.

    . These conclusions were drawn from the respondents to this study.

- Vendors of EPC systems design the systems to operate 24 hours per day, 365 days per year and rarely give much thought to the problems of long-term storage.

  - Spare parts are stored for long periods of time, but vendors warrant the parts for only three to five years so that the concern over storage extends only that far.

- Both users and vendors suggested leaving the EPC system on during dormant periods.

  - This is a "play-it-safe" approach due to lack of knowledge concerning the effects of storage on the components.

- Research in MMT 4322 should be referred to, as it will shed new light on this issue.

B. RECOMMENDATIONS

1. ARRCOM SYSTEM DEVELOPMENT CENTER

- ARRCOM should establish or support a technical group to provide long-range planning for the ammunition plant modernization program, to coordinate all EPC systems activities between operating contractors, and to moderate the use of outside contractors in all phases of an EPC systems installation.
  - This group should establish and maintain control over:
    - An extensive documentation center.
    - A spare parts management program.
    - A skilled personnel tracking program.
  - Operating contractors should be represented in this group.

2. PROCUREMENT PROCESS

- EPC system layaway considerations should be incorporated into the initial bid solicitation.
  - Responses to the solicitation should be evaluated for system lifetime costs, including spares, maintenance, power consumption under various operational modes, and for layaway/reactivation costs.
  - These should be evaluated during development and modified if necessary.
  - Component degradation data should be requested from all vendors based upon postulated storage conditions.

  - Inherent reliability calculations should be made.

- Spare parts and testing equipment for the spares should be funded with the initial procurement.

- Complete and up-to-date documentation, below the board level, should be requested in each solicitation. Documentation should be revised to show "as built" condition when the plant is proven out.

  - Software documents for both source and machine language codes should also be included.

3. STANDARDIZATION

- Very definite attempts should be made to standardize the systems used in the various EPC projects.

  - As much standardization as possible would reduce the number and types of spares carried and:

    - Maximize the usefulness of the available skilled personnel.

    - Provide leverage with the vendor for support.

    - Reduce documentation proliferation.

  - Such standardization requires choosing vendors with broad compatible product lines that will be effective in handling the requirements of the majority of the ammunition plants.

- Broad standardization of equipment would allow the operating contractors more responsibility for the systems and reduce the number of vendors involved in the entire process.

4. DORMANCY TESTING

- ARRADCOM should continue to broaden its testing program which determines the effects of long-term dormant storage on EPC systems.

    - Vendors have no interest in such testing unless fully funded.

    - Users have no need generally. Some users are waiting for the recommendations of this report and other ARRADCOM reports before doing anything with their systems.

- The tests should be broadened to include:

    - The use of anticorrosive vapors for protection.

    - Various types of environmental control.

    - The use of remote diagnostic centers for system reactivation.

5. SYSTEM LAYAWAY

- Based on survey, and discussed later in the report, systems should be laid away for two years between reactivations.

    - These systems should be protected with plastic bags as discussed later for dust control and should remain in a computer type of controlled environment.

    - Spare parts must be treated in the same manner as the systems.

6. THIRD-PARTY MAINTENANCE COMPANIES

- The use of third-party maintenance companies should be considered for maintaining the EPC systems over extended periods of time.

  - These companies will maintain the entire automated line.
  - They will keep a cadre of personnel trained in the necessary specific systems available.
  - Many maintenance service companies will manufacture or obtain obsolete parts for the older systems.

- Third-party maintenance companies are not interested in single plant contracts, preferring to handle multiple plants.

III INDUSTRY TRENDS

III INDUSTRY TRENDS

A. INTRODUCTION TO PROCESS CONTROL

1. DESCRIPTION

- Process control is defined as the use of monitoring instruments and control devices to measure and effect changes on one or more variables to ensure safe, timely and efficient operation of machines and other equipment required in a manufacturing process.

  - While processes may be categorized by the type of materials which are to be effected (i.e., fluids, bulk solids, sheeted and/or webbed materials, and discrete pieces), the concept of control and its objectives remain much the same for all types of materials.

- Electronic process control refers to the use of one or more computers to aid or actually perform the control functions required to effect change in a manufacturing process.

  - Control is the decision-making operation which compares the measured state of a process with the desired conditions and decides how the variables should be manipulated.

  - In electronic process control, this decision-making operation is effected by one or more computers. The manipulation of the variables may also be effected by a computer either in a fully off-line situation (indirectly where control problems for a particular process are worked out and the information used to design better control system configurations or to provide optimum controller settings) or in a direct digital control (DDC) system where a digital computer assumes all control computations required and generates signals to the final controlling elements.

- Current process control systems operate (with computer and/or human interface) in a real-time mode in either closed-loop or open-loop configurations.

  - Closed-loop systems generally exclude the human interface, but may be only a smaller part of a larger open-loop system. Closed-loop systems and, more and more, DDC systems operate in real-time. They are generally superior in processes requiring reaction times of less than one minute on a repetitive basis and in processes regarded as unsafe for human intervention.

  - Open-loop process control systems require an interface with one or more skilled human specialists who are responsible primarily for monitoring displays of feedback control systems' parameter data, implementing the computer controlled decision matrix algorithms, and then activating operator controls in accordance with computer-made decisions to effect necessary change to the process.

  - Another term often used in referring to open-loop control systems is the operator guide system. In this system, a skilled human specialist sets knobs, dials, or switches to control the operation of the plant based on the information supplied by the control computer.

- The essence of control theory is based on mathematical models developed empirically to satisfy the need for higher levels of safety, increased levels of accuracy in process tolerances, better economies of process or production scale, and increased levels of system performance.

  - Since an increase in productivity, safety levels, etc. in a single stage of a process can have adverse effects on any other stage of the total process system, it becomes necessary in any evaluation to analyze these effects.

- The analysis of the total process control system can be carried out with mathematical methods, experimental observation, simulation, or a combination of these methods.

  - Of the three, mathematical methods are the least expensive but are limited to rather simple processes. As the complexity of the system grows, the need for more sophisticated analysis tools becomes necessary.

  - Experimental observation is the most expensive method since it requires the installation of the actual control equipment to be used in later full-scale operations.

  - Today, simulation, where the entire process control system is duplicated in computer software, plays a critical role in the development, testing and implementation of process control systems. It is capable of handling complex systems based on empirical data being mathematically and graphically manipulated without the requirement of procuring and installing process control equipment first.

2. BRIEF HISTORY AND TRENDS

- Before the development (in the late 1920s) of the pneumatic controller with its proportional and integral (reset) modes that were field tunable and the proportional-derivative (PID) three-term controller (in 1942), most process control had to be implemented locally and manually.

- The pneumatic transmitters that were developed in the mid-1930s led to the first use of centralized control rooms with large control panels in the early 1940s.

- The development of the PID three-term controller in 1942 also marked a departure from the theoretically based development of control systems. It marked the beginning of control system developments in plants.

- While most controllers through the mid-1950s were pneumatic, the first electronic controllers were marketed commercially as early as 1951.

  - DC electronic controllers, based on transistor-operational amplifiers, started to gain market share significantly in 1960 but did not surpass the market for pneumatic controllers until 1970.

  - Programmable controllers (PCs) first became available in 1970.

- The first electronic analog computer was developed at the Foxboro Company of Foxboro, Mass., in 1938. The first installation of a computer-controlled system occurred in 1959 when the industry buzz-word was "adaptive control."

  - Some limited closed-loop computer control was used as early as 1955 in aircraft flight control decisions, in 1958 in monitoring in electric utilities, in 1959 in supervisory control in a refinery, and in 1960 for supervisory control in a chemical plant.

- Digital computers were first used in the process control field in 1955 to simulate a process control system configuration. The first use of DDC was around 1962.

  - Centralized digital control was the theme in industry in the period from 1962 through about 1974.

- Initially, the central computers were large mainframes; but as minicomputer reliability grew, they rapidly became the heart of the electronic process control system.

  - As minicomputer power grew, hierarchies of minicomputers were constructed with the aim of total plant control, as shown in Exhibit III-1.

  - One respondent in INPUT's survey is planning for 30,000 control loops. At the current stage, 8,000 loops are under computer control.

- As integrated circuit technology developed and the microcomputer came into being, these technologies moved into the process control field.

  - Programmable logic controllers (PLC) for single loop control were placed in the field or at the machining location to control individual operations.

  - The name has now changed to programmable controllers, and they contain all the elements of full computers. They can control from one to about 2,000 loops and are rugged enough to operate in a normal factory environment or under adverse field conditions.

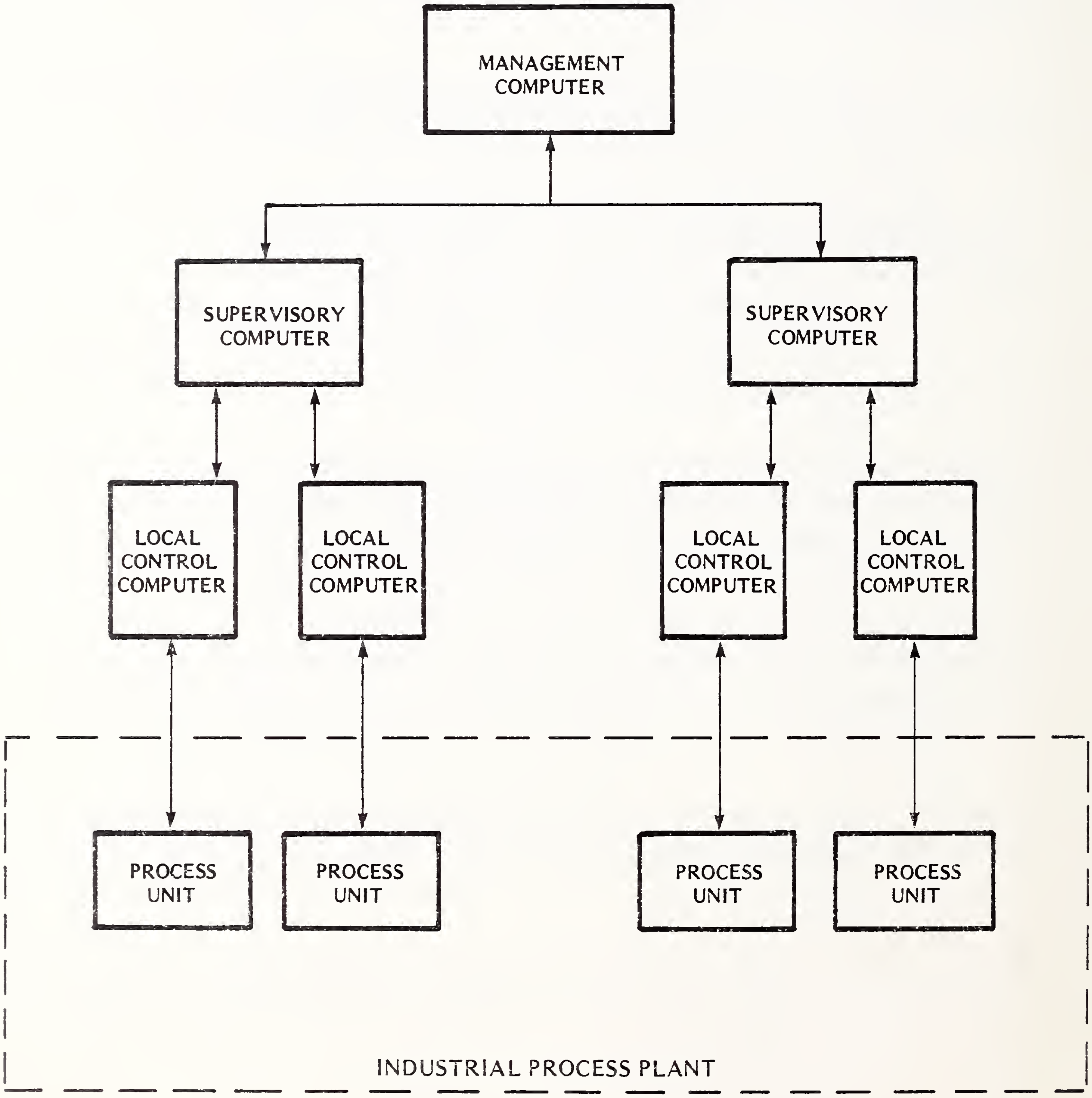
- This use of PCs is called distributed control, and the term data highway is in vogue describing the information path among the computers and programmable controllers.

  - This trend toward distributed or decentralized control will intensify during the eighties because several advantages accrue from a distributed system design.

    . Portions of the process can be automated quickly, providing an early testing of the approach and perhaps some productivity gains.

EXHIBIT III-1

HIERARCHICAL ORGANIZATION OF AN ADVANCED PROCESS CONTROL SYSTEM



  - A portion of the system may fail without causing the production line to stop.

  - No single control point is extremely critical so the costs of achieving reliability through redundancy are reduced. It is less expensive to add redundant equipment in a few critical areas than it is to provide duplicate central control computers.

- The evolution of digital computer control systems over the past 15 years is shown in Exhibit III-2.

- While the eighties will emphasize practical distributed control for increased systems reliability, the R&D efforts will be on developing sensors that are more accurate and able to measure more variables.

  - Distributed control will remain the predominant mode during the 1980s.

- The early major industrial users of electronic process control (EPC) systems in the first half of the 1960s were the large process industries.

  - Chemicals.

  - Utilities.

  - Petroleum production and refining.

  - Steel production.

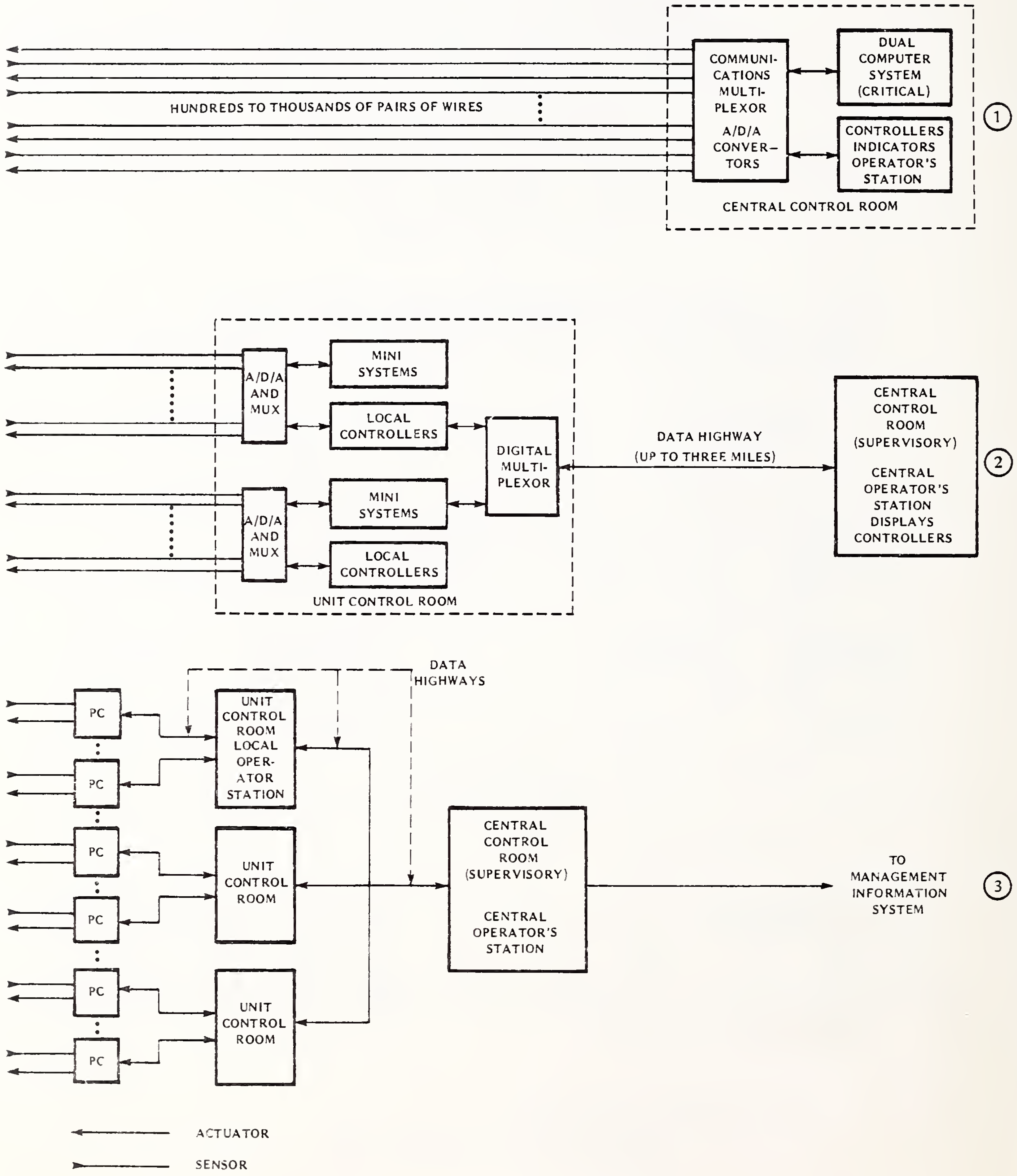
  - Pipelines.

- More recent process industries that have become major users of computers to control manufacturing are:

  - Pulp and paper production.

EXHIBIT III-2

EVOLUTION OF DIRECT DIGITAL CONTROL SYSTEMS


HUNDREDS TO THOUSANDS OF PAIRS OF WIRES
COMMUNI-CATIONS MULTI-PLEXOR
A/D/A CONVER-TORS
DUAL COMPUTER SYSTEM (CRITICAL)
CONTROLLERS INDICATORS OPERATOR'S STATION
CENTRAL CONTROL ROOM
①
A/D/A AND MUX
MINI SYSTEMS
LOCAL CONTROLLERS
DIGITAL MULTI-PLEXOR
A/D/A AND MUX
MINI SYSTEMS
LOCAL CONTROLLERS
UNIT CONTROL ROOM
DATA HIGHWAY (UP TO THREE MILES)
CENTRAL CONTROL ROOM (SUPERVISORY)
CENTRAL OPERATOR'S STATION DISPLAYS CONTROLLERS
②
DATA HIGHWAYS
PC
PC
PC
PC
PC
PC
UNIT CONTROL ROOM LOCAL OPER-ATOR STATION
UNIT CONTROL ROOM
UNIT CONTROL ROOM
CENTRAL CONTROL ROOM (SUPERVISORY)
CENTRAL OPERATOR'S STATION
TO MANAGEMENT INFORMATION SYSTEM
③
ACTUATOR
SENSOR

- Food and beverage.

- Nuclear power generation.

- Computers have been involved in aspects of the discrete manufacturing process since the early 1960s, but they have only recently been involved in controlling those processes. The major discrete manufacturing industries that have pioneered the use of computer-controlled production lines or local machining operations are:

  - Automotive.

  - Aerospace.

  - Machine tools.

- The increasing use of microcomputers and programmable controllers will allow manufacturing operations of many sizes to automate portions of the production process efficiently.

  - The greatest growth during the eighties in the process control industry will take place in the discrete manufacturing sector.

3. MARKET SIZE

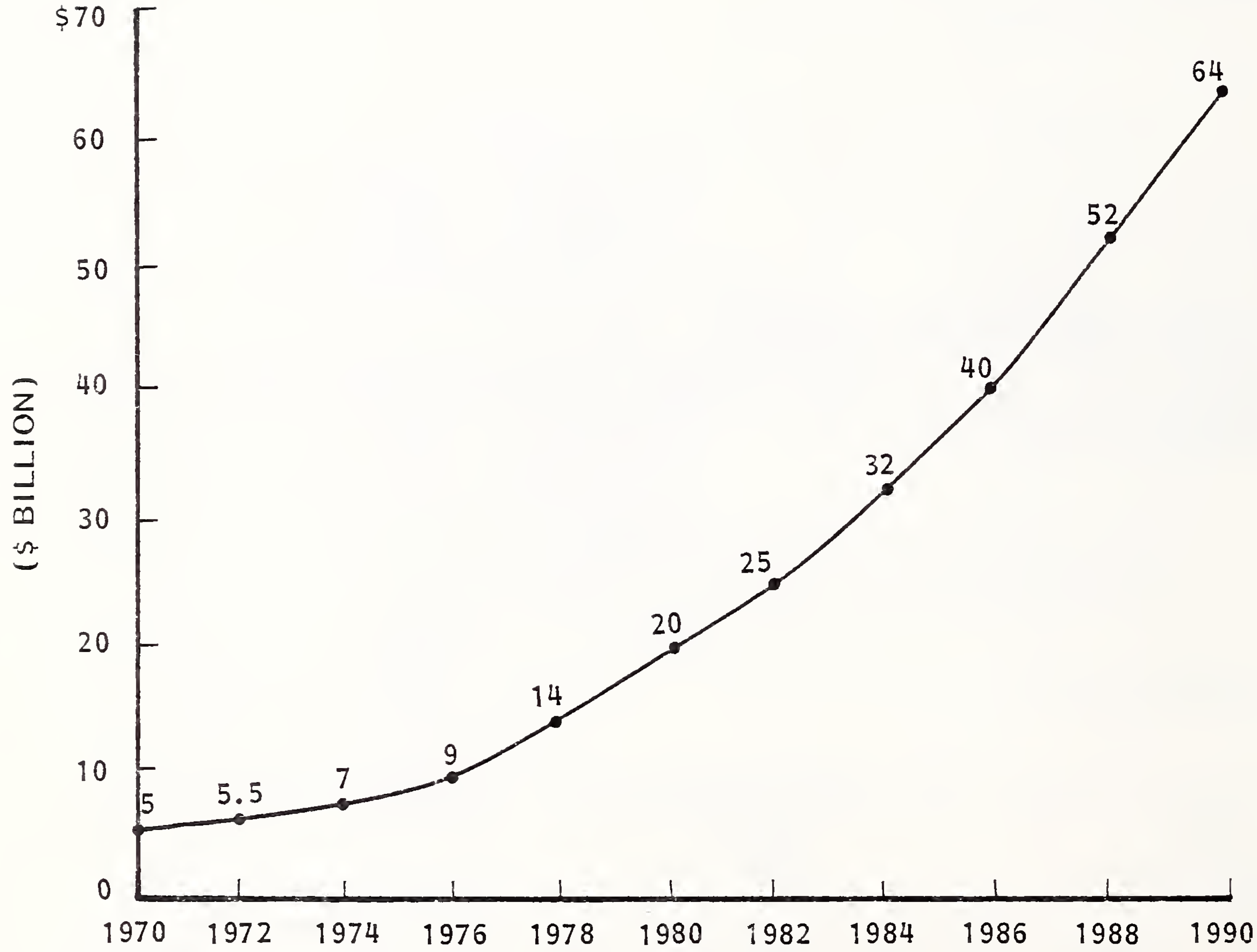
- There is no need in this study to do a definitive sizing of the process control market.

  - However, some feel for the size of the market is useful in any industry description.

- The process control market growth figures shown in Exhibit III-3 have been adapted from those published by the Instrument Society of America (ISA). They include all aspects of the control industry such as:

EXHIBIT III-3

PROJECTED TOTAL SPENDING FOR PROCESS CONTROL EQUIPMENT, 1970-1990



COMPOUND ANNUAL GROWTH IS < 14% / YEAR

- Analytical instruments.
- Computers and computer peripherals.
- Controllers, counters and timers.
- Data display systems.
- Final control elements.
- Packaged control systems.
- Sensors, transducers and transmitters.
- Signal conditioners.

- The electronic process control system forecast shown in Exhibit III-4 is based upon projections published in the January 13, 1981, issue of Electronics Magazine and, while it represents only a portion of the total spending, it is still considerably more conservative than the ISA-based forecast.

  - The compound growth rate for the industry has been between 10% and 15% per year over the last 10 years. The programmable controller portion will probably grow at 20% to 22% per year during the next 10 years, but the overall industry growth will remain in the 10-15% range.

  - INPUT believes these estimates are adjusted to exclude inflationary factors so that they reflect real growth.

B. MAINTENANCE TRENDS IN THE COMPUTER INDUSTRY

- The Army should be aware of the major maintenance trends in the industry.

EXHIBIT III-4

PROCESS CONTROL COMPUTER SYSTEM FORECAST

($ MILLIONS)

SYSTEM	1979	1980	1981	1984
DIGITAL	$190	$212	$232	$304
ANALOG	40	42	46	55
TOTAL	$230	$254	$278	$359

SOURCE: ELECTRONICS MAGAZINE JANUARY 13, 1981

  - These trends can impact both the availability and quality of maintenance at ammunition plants.

  - Some methods and procedures being developed in the computer industry may be useful to the Army.

  - The factors discussed in this section should be taken into consideration in future equipment and maintenance specifications and procurements.

- This chapter covers a number of important trends in the computer industry's maintenance functions. INPUT has attempted to highlight those areas that could be useful to the Army.

  - INPUT has a Field Service Program which prepares eight to ten reports annually on the subject of maintenance.

  - Clients benefit from studies on management, control, trends, service levels, and other current topics on maintenance.

  - This service may be of value to ARRADCOM.

I. DESIGN FOR MAINTAINABILITY

a. Equipment Design for Reliability and Serviceability

- Beginning in the mid-1970s, a few equipment designers began to place increasing importance on reliability and serviceability as a design criteria.

  - Although the importance of this criteria varies substantially from manufacturer to manufacturer, there is no question that this is an industry trend.

- Design for reliability and serviceability is taking many forms. Some of these are:

  - Redundant circuitry.

  - Use of components operating well below design limits.

  - Improved materials used on components that have a wear factor with which to contend (e.g., magnetic heads).

  - Built-in diagnostics.

  - Built-in instrumentation and/or separate but specialized instrumentation.

  - Redundant functional modules.

  - Modular design.

- No one manufacturer currently uses all of these design approaches, but most either have or plan to have several of these features designed into their product lines.

  - An outstanding example is that of Tandem, a California-based computer manufacturer, whose standard product is a dual processor minicomputer designed so that one processor automatically takes over from the other should it fail. Failure detection and switching are built in and are automatic.

  - IBM uses triple redundant circuitry in many of its newer products. As the system runs, the outputs from three identical circuits (which operate in parallel) are compared. If the output of one circuit differs from the other two, the system automatically chooses one of the circuits in the majority.

b. Testing

- The increased availability and lower cost of intelligence has spurred the development of two new primary instrumentation approaches to maintenance that will be increasingly evident in the next few years:

  - Systems designed to accommodate remote diagnostics.

  - Standalone maintenance "computers."

- Remote diagnostics (which are discussed in more depth in Section B.3 of this chapter) are particularly suited to installations where all the equipment has been provided by a single vendor.

- There are two approaches to testing which, alone and together, constitute an industry trend. These are:

  - Built-in testers (instruments).

  - Use of microdiagnostics.

- Microdiagnostics can be hardwired or loadable. They can be tailored to fit differing requirements. For example, a simple test designed for user operation may be provided, while complex tests designed to be used by skilled service personnel can be run when the occasion calls for it.

- Microdiagnostics will be used extensively on-site in multivendor installations.

- There is also a trend toward incorporation of controllers and other decision-making devices into interfaces permitting direct device attachment to buses or channels.

  - These "smart front ends" provide an opportunity to build in diagnostic systems capable of monitoring and self-testing both interfaces and peripheral devices. They greatly enhance the ability of service people to isolate faults in multi-element systems.

2. PERSONNEL TRENDS

- Demographic, motivational and industry growth forces have combined to create a substantial shortage of skilled service personnel in the computer industry.

  - This shortage, presently estimated by INPUT at 25,000 people in the U.S. alone, will continue to intensify as new systems and equipment are added to the already substantial installation base.

  - The computer industry, which used to obtain the majority of its skilled technicians from the military before the days of the all-volunteer service, has simply not been able to recruit and train the quantity and quality of people it needs.

- Because of this phenomenon, the computer industry is being forced to change the methods by which it delivers maintenance. As a consequence, the skills mix is also changing. This section projects the evolution of the "serviceperson of the future."

- By the mid-1980s, the service organization will evolve into a three-tiered structure. At each level, different types of people will be required to meet the service demands of the integrated computer/office/communications systems in place at that time.

- Within this hierarchy, each level has its own role in the service organization, performing different functions and interfacing with customers in different ways and often at different levels (i.e., the skills, training, handling and compensation requirements will be significantly different for each category).

- Due to economic necessity, some of the functional requirements of the three levels may overlap, depending on customer base, product line density, geographic dispersion of specific products and other factors. In most organizations, however, the lines will be distinctly drawn.

- The three classes of service personnel and their distinguishing characteristics are described as follows:

a. Local Field Service Technician (LFST)

- LFSTs exist primarily to handle routine service functions such as:

  - "Cookbook" preventive maintenance diagnostics and routines.

  - Repair at the module or unit replacement level.

  - Cleaning and burnishing of mechanical components.

- Skill and technical training requirements for LFSTs are relatively minimal.

b. Local Field Support Specialist (LFSS)

- LFSSs serve as backup to the LFSTs, taking charge of problems the latter cannot deal with. They must have a thorough grounding in the theory of operations of the systems with which they will come in contact.

- Most positions will require the equivalent of a four-year degree. Most will need to comprehend both software and communications.

- LFSSs will be generalists capable of making decisions on nonroutine problems as they come across a broad spectrum of products and systems.

c. Central Site Support Specialists (CSSS)

- Central site support specialists are resident at headquarters or regional locations and are responsible for dealing with highly technical problems beyond the capabilities of field personnel.

- CSSSs are specialists in every sense of the word. They have in-depth knowledge of specific products; indeed, their knowledge may be limited to an individual subset of a complex system; for example, the central logic unit or the operating system software package.

- The change in the distribution of skills in a field service organization is shown graphically in Exhibit III-5.

3. NEW MAINTENANCE TECHNIQUES

- This section addresses four "new" maintenance techniques that are gaining rapid acceptance throughout the computer industry:

  - Remote diagnostics.

  - Self-maintenance procedures.

  - Depot maintenance.

  - System support centers.

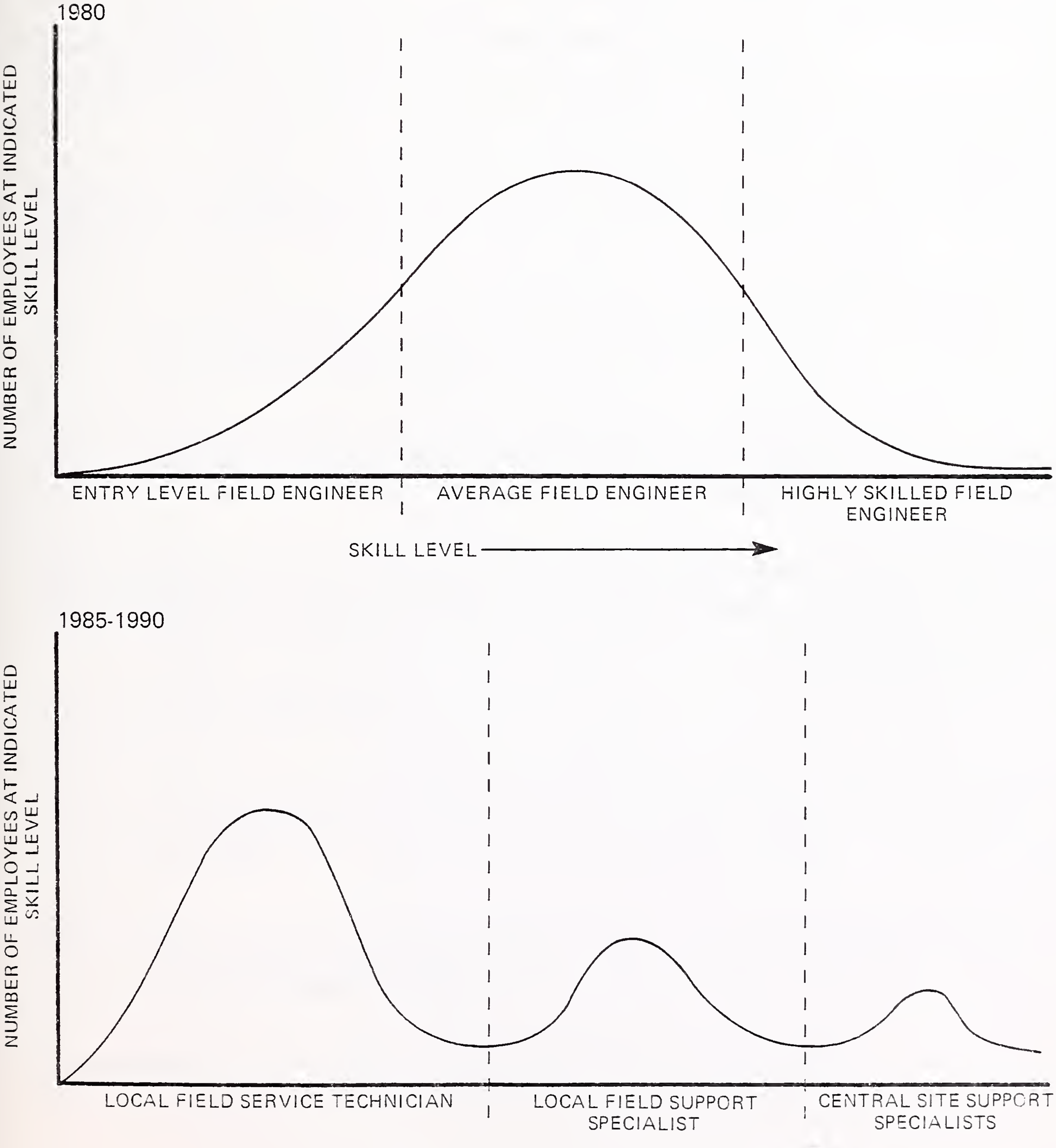
- All these methods could play an important role in the achievement of the Army's objective of high long-term reliability under dormant conditions.

a. Remote Diagnostics

- Remote diagnostics have been available for several years, but vendors are just beginning to exploit the potential of these techniques.

EXHIBIT III-5

SHIFT IN DISTRIBUTION OF SKILL LEVELS OF FIELD SERVICE PERSONNEL



  - Although development of remote diagnostics is being driven by escalating labor costs and the shortage of qualified service personnel, vendors are finding that they can actually provide better service at less cost with remote diagnostics.

  - A side benefit to the implementation of a remote diagnostic system is that service levels tend to become standardized across all geographic regions.

- INPUT recently, as part of its on-going research, surveyed the U.S. computer industry and found that only 10% of vendors had no plans for remote diagnostics.

  - Of the remaining 90%, one-half already have some capability.

  - The other half had plans to implement remote diagnostics for new products, with scattered reports of retrofitting this capability to older equipment.

- In the technological sense, the limiting factor is not in the robot and communications segment, but in the quality and reliability of the diagnostics themselves.

  - Remote access and control of operator and maintenance consoles is a relatively simple electronic achievement.

  - Remote control, however, will not improve the reliability of the data reporting capabilities.

- At present the value added in most instances is the quicker introduction of interpretive capabilities to the local situation via remote hook-up.

  - One company reports that as many as 15% of the calls on peripherals are now avoidable because of their remote verification process which aids the dispatch center in directing users to call their mainframe maintenance vendor in those cases where the fault lies with the mainframe.

- Equipment reliability has paradoxically created a need for remote diagnostics as well as for more reliable diagnostics generally.

  - The evolution of reliability in equipment, following design principles developed for aeronautics and space programs, and employing redundancy and backup systems, has proved to be a two-edged sword in maintenance.

  - Experience levels and learning rates of field engineers have traditionally depended upon positive reinforcement derived from troubleshooting natural failures.

  - With more reliable equipment, therefore, the field engineer has less practice with failures and can lose individual proficiency.

- There are many different remote diagnostic schemes in place and under development. For the purpose of this report, INPUT has selected Digital Equipment Corporation's (DEC) new system as a particularly meaningful example, since it is designed to handle the class of systems encountered at the Army's munitions plants.

- DEC's system is entitled "Remote Computerized Diagnostic" (RCD). It is used with PDP 11/70-based systems and the VAX 11/780. It became operational in early 1980.

- Based on the performance figures available in late 1980, DEC's reported results are extremely significant.

    - Thirty percent of all faults are solved over the telephone by having the on-site operator take some simple corrective action without any participation by a skilled service person.

    - RCD's success rate in isolating the failed part of the system in the remaining 70% of the reported faults is 90%. Service technicians are immediately dispatched with the required repair parts in hand.

- One of the principal features of the DEC system (and others like it) is centralized fault reporting, enabling the automatic recording of all system failures and fixes.

    - This is consistent with ARRADCOM's approach and what it is attempting to accomplish.

    - Statistical analysis of this data can then be used to make a major contribution to reliability improvement programs, which are of particular interest to the Army.

    - ARRADCOM has the data for extensive testing and improvements over the next 20 years.

- DEC's RCD system is shown schematically in Exhibit III-6.

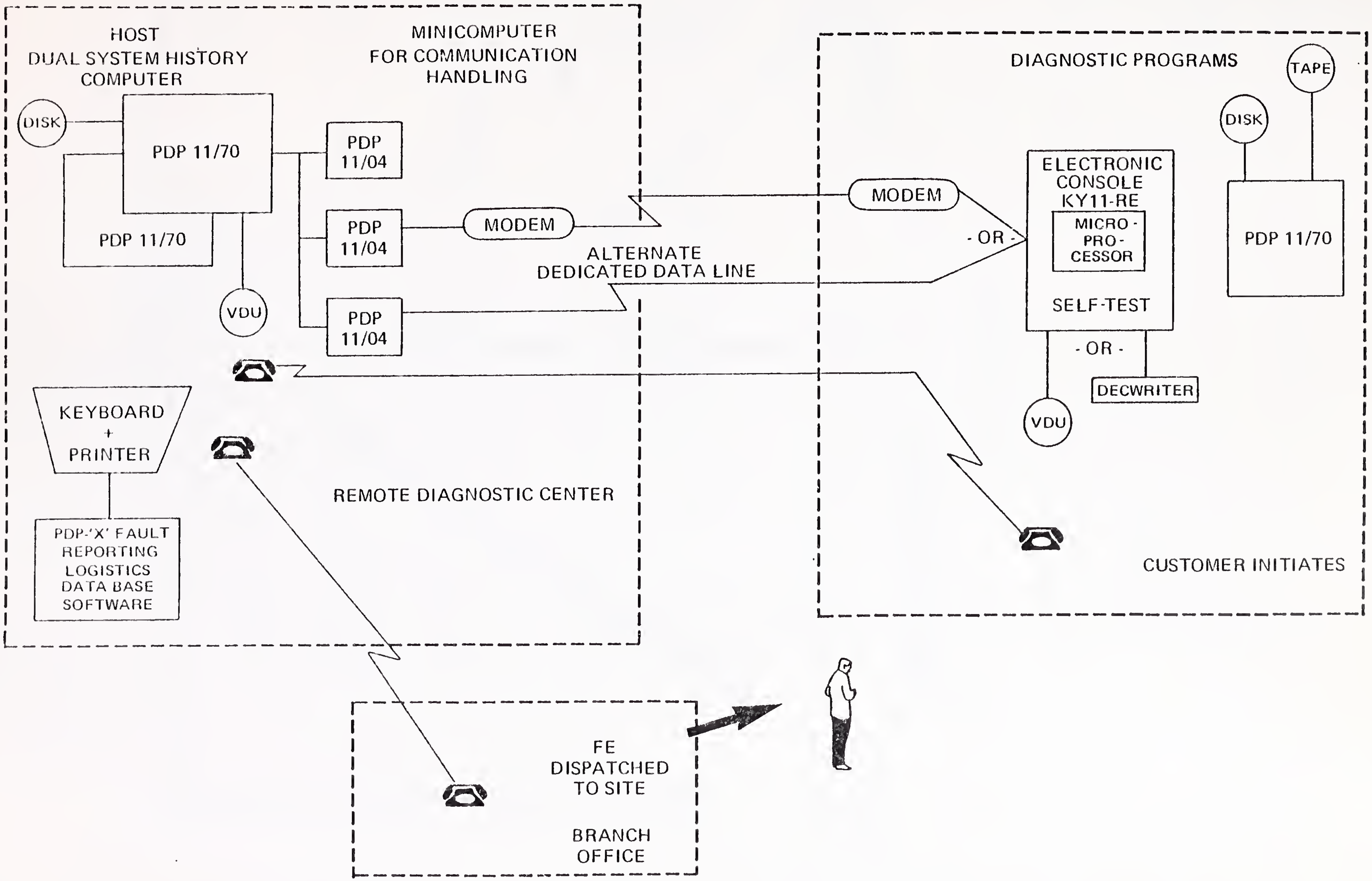
    - The host system, resident at the remote diagnostic center, consists of dual PDP 11/70s interfaced to a network controlled by PDP 11/04s. The latter provide message switching and auto-dial facilities.

    - The user's system requires a special console, designated the KY11-RE, which replaces the standard operator console.

        - The console, which contains a built-in microprocessor, has its own self-test facility so that the operator can determine if the console itself has a fault.

EXHIBIT III-6

DEC REMOTE DIAGNOSTIC CENTER



    - VAX systems have the console's special facilities built in.

  - An on-line disk storage unit at the host system contains data on customers, their system's performance history, and their machine configuration.

  - Diagnostic routines are maintained at the customers' sites and kept on disk and/or tape.

- System operation procedures for the DEC RCD system are shown diagrammatically in Exhibit III-7.

  - When a fault is detected, the customer initiates the procedure by telephoning the "Service Response Group" (SRG) located at the remote diagnostic center.

  - The SRG engineer logs the call and discusses the fault with the customer. If he determines that the fault is operator-induced or is an environmental problem, the customer is advised accordingly. If it is a software problem which the SRG engineer is not able to resolve himself, the contact will be passed to a software support group.

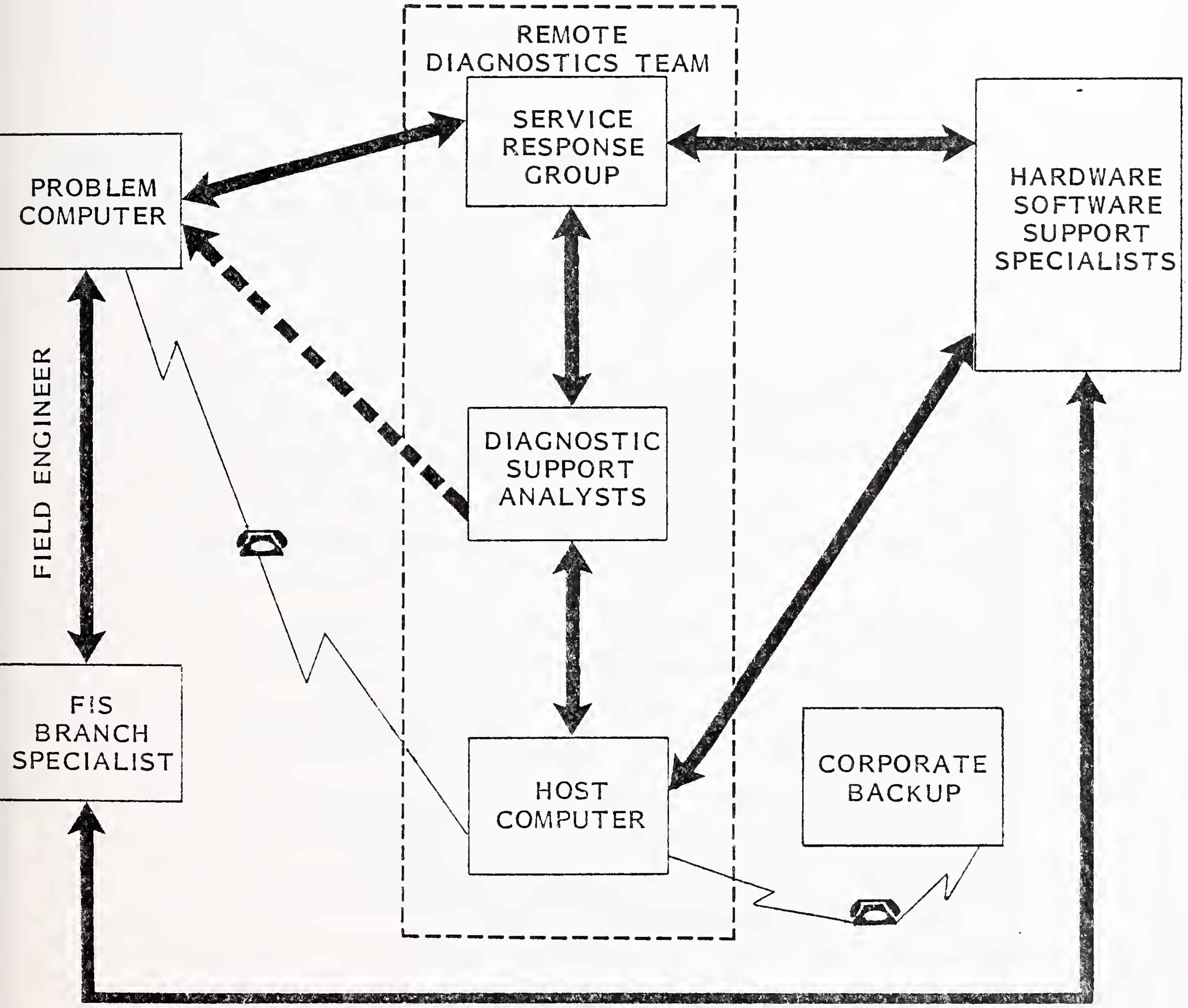
  - If the fault is determined to be a straightforward peripheral failure, the SRG passes the call to the appropriate local service branch which dispatches a field engineer to the customer's site.

  - If the fault is thought to be a mainframe or system problem, remote diagnostics will be used.

    - To operate the remote diagnostic system, the customer first removes his storage media or ensures that it is write-protected. He then switches the console to "remote," which effectively passes control of the system to the remote diagnostic center.

EXHIBIT III-7

DEC SYSTEM OPERATION AND PROCEDURE



- The local service branch is immediately advised to enable pre-scheduling of a possible visit by a field engineer.

- Diagnostic tests are then run and monitored by the SRG engineer until a fault or test failure is encountered. Test results and data are displayed on a DEC writer at the remote diagnostic center.

- A local service branch is then advised to dispatch a field engineer who will be armed with the parts needed to repair the fault.

- Once the problem is resolved by repair, the field engineer informs the SRG engineer who then reruns the appropriate diagnostics to prove that the repair has been effected. Control is then returned to the customer.

- One of the more interesting features of the DEC system is that the SRG can run parts of the preventive maintenance test schedule. This is particularly attractive because these tests can be executed during non-prime shift hours.

- On the VAX 11/780, when an operator suspects or detects a hardware error, he:

  - Mounts a diagnostic disk pack.

  - Loads a diagnostic floppy disk in the console.

  - Selects "remote diagnostic" on the console switch.

  - Calls the diagnostic center.

- Once he has done this, no other activity is required from the site.

- The diagnostic center runs the 11/780 automated diagnostic package or operates the diagnostic console manually.

- If a problem is found, then a field engineer is sent with the required equipment and replacement modules.

- Using this approach, reactivation could be effected under the control of the remote diagnostics center.

b. Self-Maintenance Procedures

- In an effort to cover the shortfall of maintenance personnel, some vendors are encouraging the direct participation of their users in the maintenance process.

- Most vendors view self-maintenance as one of a series of elements in a complete maintenance strategy.

    - Other elements include, for example, the use of system support centers, modular equipment design and remote diagnostics.

- Self-maintenance programs are not simple to implement. Vendors usually must provide:

    - Special diagnostic routines designed to be run by the unskilled.

    - Thorough documentation.

    - User training programs.

    - Special product design and packaging, in some cases.

- Nonetheless, self-maintenance programs are beginning to be introduced and INPUT believes they will be a growing trend.

  - IBM is experimenting in this approach with its new 3101 display terminal and 3102 thermal printer. The self-maintenance concept was engineered into these products from the very beginning. In fact, IBM offers no alternative service policy on these products.

- A major driving force to self-maintenance is the growing use of distributed processing.

  - By 1982, INPUT estimates that 30% of the total installed base of computer equipment will be operating in a distributed environment.

  - Distributed systems are particularly suited for user self-maintenance because communications facilities are already there, the equipment at a given site is relatively simpler than large systems, and the expense of on-site service coverage is usually not justified.

- Today, self-maintenance is not common. Most self-maintenance functions are limited to running diagnostics using cookbook procedures that can be learned by anyone.

  - In a few cases, users are performing board or module replacement.

  - In even fewer cases, users are taking prime responsibility for all maintenance functions. This kind of activity tends to be restricted to high-technology companies who already have employees with the right set of skills. For example, it is fairly common for an electronics equipment firm to maintain test equipment manufactured by someone else.

c. Depot Maintenance

- Depot maintenance, often provided together with user self-diagnostics, is a third maintenance technique growing in importance.

- Few process control vendors supply such a service today, but INPUT sees this as a trend with computer manufacturers which may spread to process control vendors.

- Depot maintenance is practical only for equipment that can easily be packed and shipped. With the physical size of electronics packaging decreasing, more equipment will be suited for depot maintenance in the future.

- Depot maintenance offers two significant benefits to the customer:

  - It is usually the least expensive procedure.

  - The skills and equipment (both for testing and repair) found at depot maintenance centers are of the highest quality.

  - Devices sent to repair depots usually go through an exhaustive, complete test procedure rather than having attention focused only on the reported fault as is usually the case with on-site maintenance. Thus, faults other than the one that caused the system to be sent back to the depot are detected and fixed, usually at no additional expense to the customer.

d. System Support Centers

- The system support center is the fourth maintenance technique to gain new popularity. As it is being implemented today, the concept is simple: take the best expertise, equip it with the most sophisticated diagnostic tools and aids, and put these elements together in a single location accessible to all customers by both voice and data telecommunications facilities.

  - Although a few relatively small firms have had established support centers for more than ten years, only recently have the largest companies (most notably IBM) implemented them.

- By the end of the 1980s, INPUT believes there will be almost total conversion of first-line user support from the field to the support center.

  - Coupled with this shift, the maintenance function itself will become 95% logistic and only 5% diagnostic because of new diagnostic aids, both local and remote. This is almost a complete reversal of the situation as it existed in the late 1970s when most maintenance resources were spent on diagnosis rather than sparing and repair.

  - This will be important to ARRADCOM.

- The distinguishing characteristics of support centers as they are evolving are:

  - Regional or national support centers staffed with dedicated support specialists.

  - Procedural requirements for field personnel to attempt diagnosis through telephone assistance before dispatching specialists to provide physical assistance.

  - Centralization of data on symptoms and fixes.

  - Higher level functional authority vested in technical support staff management.

  - Formal communications linkage between support centers and the plants which make the equipment or design the software.

  - Integration of technical support with other support functions in diagnosis.

    - Physical planning support.

    - Configuration/systems assistance.

    - Software support.

    - Field education.

    - Engineering change control.

    - "Alert" system and status monitoring for management.

    - Asset controls, tools and test equipment.

    - Product performance tracking.

    - Maintenance-level component failure analysis.

    - Technical information dissemination control.

- A typical support center hierarchy is shown in Exhibit III-8.

  - The procedure looks and is relatively simple to effect.

- An interesting example of what one company plans to achieve with its support center operations in the software area is illustrated in Exhibit III-9. Although this is only a model, not actual results (it's too early to tell), the chart clearly shows a dramatic potential for improvement.

4. MAINTENANCE COST TRENDS

- The cost of maintenance is becoming an increasingly higher percentage of computer users' expenditures over a seven-year operating life cycle of a system. This fact is illustrated in Exhibit III-10 which shows the ratio between hardware and service costs over a typical seven-year product operating life cycle.

EXHIBIT III-8

TYPICAL SUPPORT CENTER HIERARCHY

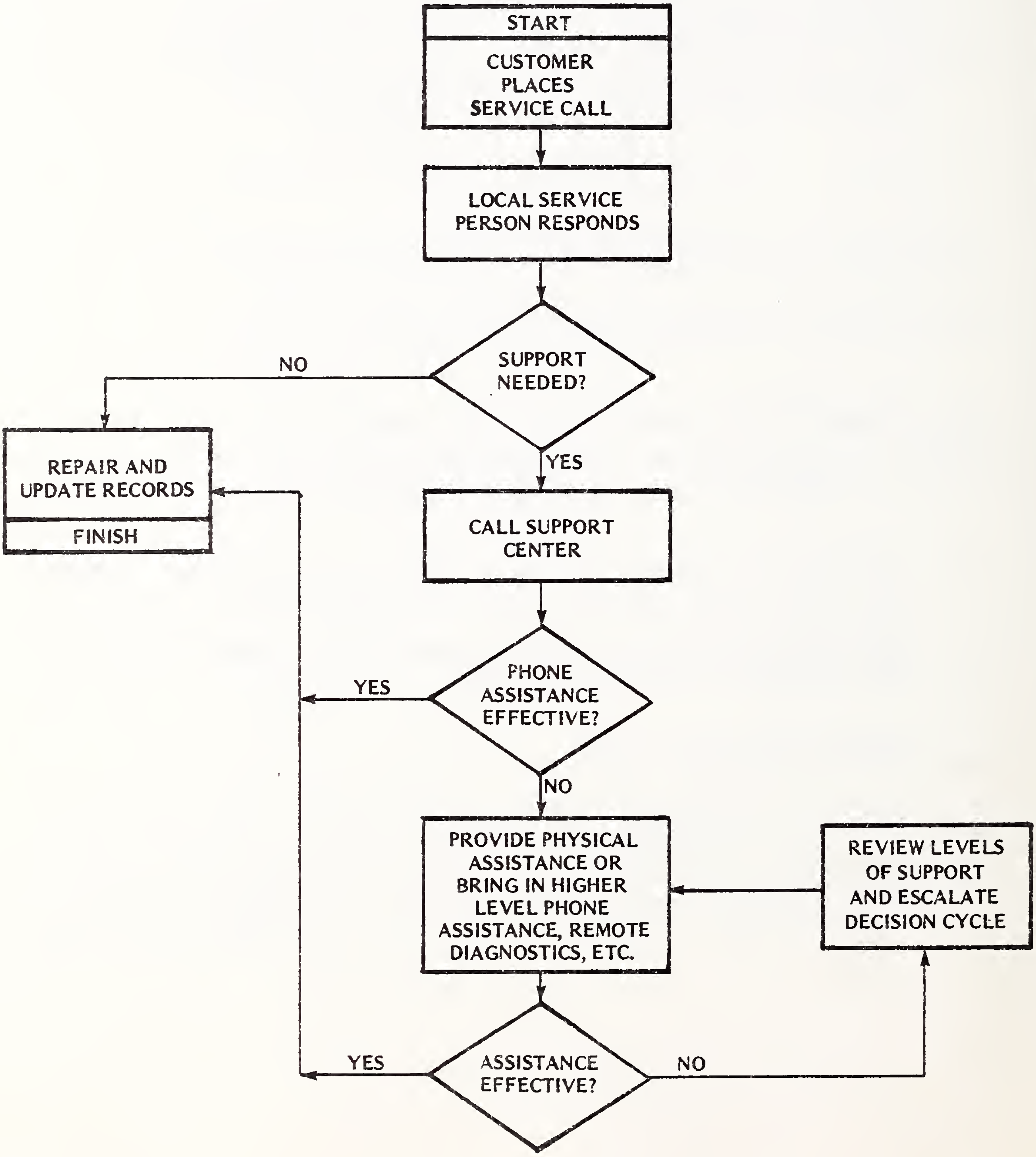

START
CUSTOMER PLACES SERVICE CALL
LOCAL SERVICE PERSON RESPONDS
SUPPORT NEEDED?
NO
YES
REPAIR AND UPDATE RECORDS
FINISH
CALL SUPPORT CENTER
PHONE ASSISTANCE EFFECTIVE?
YES
NO
PROVIDE PHYSICAL ASSISTANCE OR BRING IN HIGHER LEVEL PHONE ASSISTANCE, REMOTE DIAGNOSTICS, ETC.
REVIEW LEVELS OF SUPPORT AND ESCALATE DECISION CYCLE
ASSISTANCE EFFECTIVE?
YES
NO

EXHIBIT III-9

PLANNED RESPONSE TIME TO MAINTENANCE CALLS WITH/WITHOUT SUPPORT CENTERS

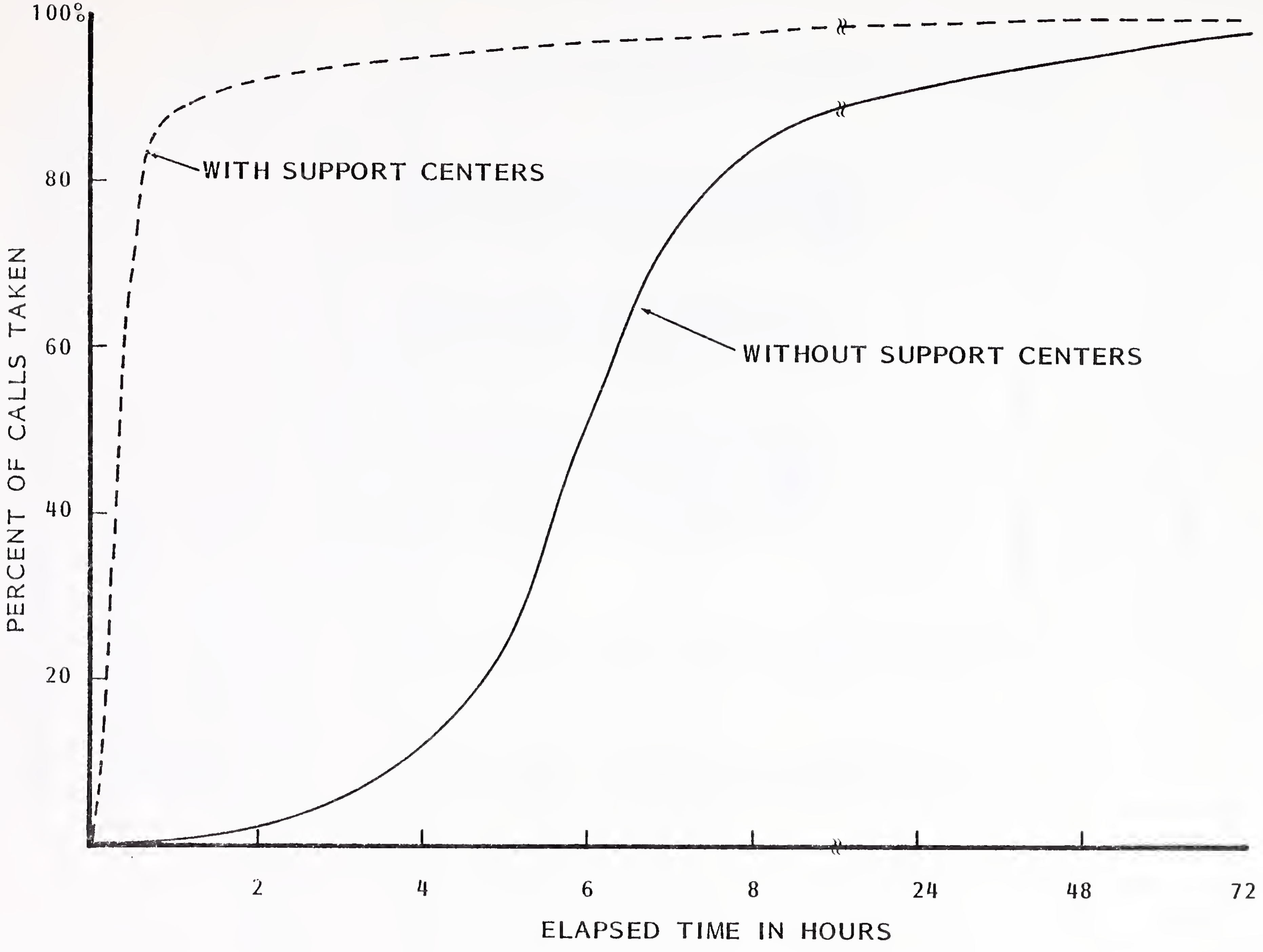
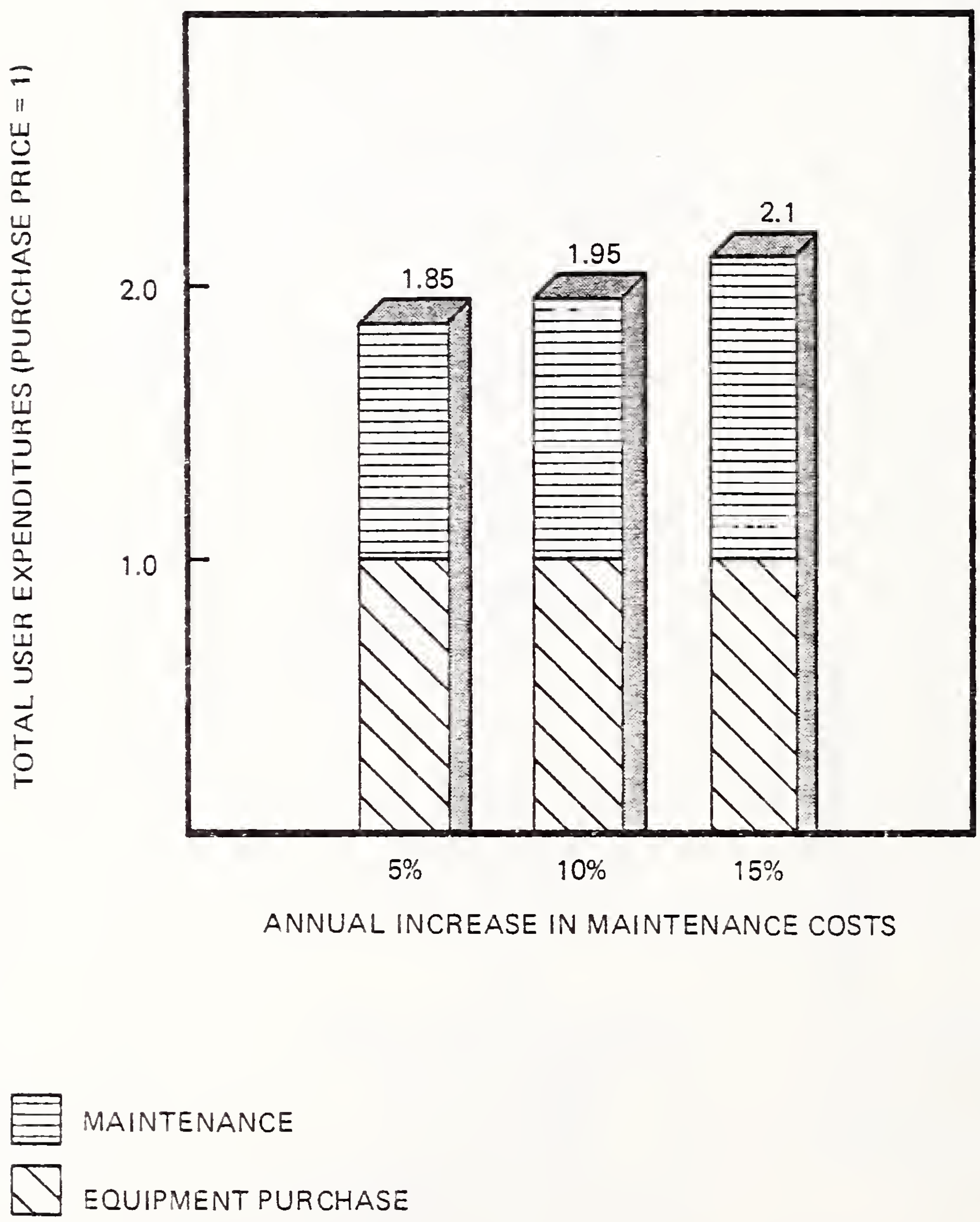


EXHIBIT III-10

TOTAL USER SYSTEM EXPENDITURES OVER A SEVEN-YEAR LIFE CYCLE



NOTE: CHART ASSUMES IN YEAR 1 THAT MAINTENANCE IS 10% OF PURCHASE PRICE

- The chart assumes current annual maintenance charges are 10% of equipment purchase price, which is typical of minicomputer systems.

- Clearly, users are making a financial commitment to service as large as or greater than their commitment to hardware as the relative price of maintenance increases.

- It is true that the costs of maintaining newer systems built with state-of-the-art technology are lower relative to older systems of equivalent power.

  - Rarely, however, are old systems replaced with ones of equivalent power, so the absolute cost of maintenance to the user in most cases is not diminished. In fact, it is often higher because of increased complexity due, for example, to the addition of telecommunications capability.

- The information processing industry has been dominated by IBM computers, Xerox office products, and AT&T communications. All three originally took a bundled approach to service.

  - Bundled means that the service charges were included in the products' rental cost.

  - Led by IBM which is generally separating service from hardware, the industry is seeing the bundling constraints crumble.

- Because computer systems have become more complex and at the same time more important to an institution's ability to function, the sensitivity to a system being "down" is becoming increasingly intensified.

  - In this environment, service becomes an imperative that can be justified at nearly any price.

5. MAINTENANCE CONTRACT TRENDS

- INPUT's research shows that computer users elect to adopt fixed-fee maintenance contracts over time and materials (T&M) by a better than 20:1 ratio. However, there is a trend toward reducing base coverage (say to a single shift) and purchasing additional spot coverage as needed on a T&M basis.

  - Computer services companies will provide both fixed fee and T&M contract alternatives to users.

- Several emerging trends are beginning to influence the composition of service agreements:

  - Increased customer involvement in diagnostic and repair procedures.

  - The shrinking size of equipment which makes depot maintenance practical.

  - More widespread use of remote diagnostics and system support centers.

- Due to these influences, some important changes in service contracts will be made.

  - On the one hand, vendors will provide much more flexibility to meet individual customer's requirements.

  - On the other hand, some products will be offered on a "take-it-or-leave-it" basis, such as depot maintenance on the IBM 3101 terminal.

  - A choice of standard plans will be available for the smaller user.

- INPUT believes that within ten years nearly all post-warranty service will be unbundled, reflecting general recognition of service as a product.

  - Unbundling means that service will be priced separately for each piece of equipment.

  - Although it is not widely used today, one is beginning to see experiments by industry leaders, particularly IBM, that point to much broader use in the future.

- Hardware maintenance costs (in relation to the installed base) will continue to increase over the next three to four years and may begin to reduce after that time as hardware becomes more reliable.

  - However, INPUT believes that service costs for maintenance will continue to increase for the foreseeable future.

    . The increasing complexity of distributed systems and attendant software will add more to software maintenance costs than cost-saving devices such as systems support centers will deduct.

    . Thus, the total cost of service as a percentage of income derived from the sale of a system is expected to increase.

- In summary, the general computer industry is definitely moving toward treatment of service as a separate product which will increasingly be procured on a "pay for what you get" and "pay as you go" basis.

6. THIRD-PARTY MAINTENANCE (TPM)

- There are two types of TPM companies in the computer industry.

  - TPM firms who rely on contracts to provide maintenance on obsolete equipment and/or mixed vendor installations and who exist largely because the manufacturers want them to exist.

    . Their prime competitive edge is price.

    - The equipment suppliers could drive them out of business if they choose to do so, simply by making it difficult to obtain spare parts, or by reducing maintenance prices.

    - Another way to preclude end user TPM is to prevent the TPM vendor from being able to maintain software.

    - INPUT uses the term end user TPM to describe this business.

  - The second class of TPM business involves the establishment of long-term contracts between a TPM firm and a manufacturer wherein the TPM firm agrees to handle all the maintenance of a product or product line within a prescribed geographic territory (which may be national or even international).

    - The TPM vendor also participates in the design phase of new products under development by the vendor.

    - In this situation, the TPM vendor becomes, in effect, a partner of the manufacturer.

    - INPUT uses the term OEM TPM to describe this business.

- In contrast to end user TPM, OEM TPM is an emerging new business opportunity. There are several premises upon which the business can be approached:

  - Offering services based upon specialized expertise; e.g., CAD/CAM, communications systems, knowledge of specialized process environments, etc.

  - Offering services based on geographic distribution.

  - Offering services based on extensive available facilities such as system support centers, repair depots, automatic test equipment, warehouse locations, transportation facilities, communications networks, etc.

- OEM TPM is receiving increased attention from major vendors, both as buyers and sellers.

  - Some large companies are seriously considering awarding OEM TPM contracts on some of their smaller product lines.

  - A few of the same companies are seriously considering entering the OEM TPM business in certain geographic areas.

- A new phenomenon that may impact the TPM business over the next few years is the interest evidenced by a few large users in getting into the business.

  - A large aerospace company, which maintains its own systems, is now offering end user TPM in a limited geographic area.

  - A large bank which maintains its own office equipment is seriously considering the creation of a subsidiary which would offer both end user and OEM TPM services.

- Although TPM accounts for less than 10% of maintenance expenditures today, OEM TPM is growing rapidly. As companies begin to view services as a profit or loss center, especially within large in-house field service organizations, INPUT expects to see more activity in OEM TPM in the next few years.

- A separate class of TPM vendor is one who will take full responsibility for maintaining facilities of which computer equipment is only a part.

  - These organizations are most often found at government installations and at both process and discrete manufacturing plants.

  - Typically, they will maintain (in addition to electronics) electrical systems, electromechanical systems, sensors, communications facilities and, in a few cases, even provide janitorial services.

  - Examples of this type of vendor are GE, RCA, TRW, Honeywell and IBM (Federal Systems Division).

- Vendor stability is a key selection criteria for these "facilities managers" because, in most cases, it is impossible to arrange for backup if the vendor quits or goes out of business.

7. TRAINING TRENDS

- To maintain a cadre of service personnel capable of skillfully servicing munitions plant control systems over a 20-year life cycle under dormant conditions is a formidable challenge.

  - The equipment is likely to become obsolete over that timeframe causing manufacturers to withdraw some or all of their support.

  - Contractor personnel come and go.

  - Learning retention (see Chapter 7, Section B) becomes extremely difficult.

- The only solution to these problems is to establish a training program that can provide long-term continuity regardless of personnel shifts.

  - The retention of skilled personnel is also a function of the challenge of the work environment.

- Every training method carries with it a difference in commitment, cost, and other advantages/disadvantages. This section examines the following four common training methods in use today:

- Lecture/lab.

- Self-study.

- Video.

- Computer Based Instruction (CBI).

a. Lecture/Lab

i. Advantages

- Lecture is the most common method of education in field engineering used today. It is also the easiest method because of its short development time and low resource requirements.

    - The development cycle of a lecture/lab course is approximately eight hours of writing for every one hour of lecture time.

    - Due to the interaction between the students and the instructor, greater student interest is maintained, providing, of course, the instructors are of high quality.

- Lecture/lab best fits the basic education courses because new employees can be evaluated easily. Due to the low development costs, lecture/lab is the least expensive method of training small numbers of students.

ii. Disadvantages

- There are disadvantages to this method:

    - The quality of courses is often inconsistent because of instructor capabilities.

- The length of classes varies because of extraneous information discussed.

- Lecture/lab requires dedicated instructors for the duration of the course.

- Resurrecting courses becomes difficult because of the reassignment of instructors - an acute problem in a long-term program.

iii. Costs

- The cost of a 20-day lecture/lab class today runs about $22,000 exclusive of student salaries. The average class size is eight people.

    - If the program were run continuously, annual costs would run about $240,000 for a one-year period.

    - Although the up-front costs of lecture/lab are low, the ongoing costs become prohibitive if large groups must be trained.

b. Self-Study Method

- Self-study is an extremely valuable training method, but it can rarely stand alone. Self-study can be used very effectively in situations where students are learning differences about products for which they have already been trained. Also, interspersed with other training methods, self-study increases the effectiveness of that method.

- The most widely used self-study method is linear, where the information is simply transposed into sections and tests. Many of the other methods of self-study offer remedial training. Their development time can be up to four times that of the linear method because they are very difficult to write.

i. Advantages

- Once the self-study course is written, it is the most inexpensive field training method. When used with other training methods, such as video or self-study, it is extremely effective. Also, self-study tends to compress the course because the extraneous information found in the classroom is deleted. Industry standards estimate a 2:1 time compression. Some immediate advantages of self-study are:

  - The quality of courses is consistent.

  - Large numbers of students are handled quickly.

  - Courses are available anywhere in the field at any time.

ii. Disadvantages

- A major disadvantage of self-study is the time required to develop a self-study package. The linear method, which simply takes information and transposes it into sections, requires approximately 26 hours of writing for each hour of instruction.

- It is very difficult to measure or control the effectiveness of self-study. No records of who has been trained, or their performance level, can be made.

- Another difficulty with the self-study course is that when it is administered in the field the proper time or facilities required may not be allocated.

- Students also experience difficulty in understanding and retention because of the lack of instructor-student interaction.

iii. Costs

- Since each hour of self-study requires 26 hours of writing (this is based on the linear method), a 20-day course would require 520 days of development time, or 4,160 hours. A breakdown of the total price of a 20-hour course is:

- 4,160 hours/160 hours = 26 months
- Instructor costs, 26 months = $60,658
- Printing costs, estimated = $12,000

Total = $72,658

- From a straight cost standpoint it appears to be very attractive. However, the following questions need to be answered.
  - Is a lab required for the course?
  - If there is a serious maintenance problem in the field, how quickly can it be resolved?
  - How are the results of the course going to be validated?
  - Who is available if the student has problems understanding the material?
- The solutions to these questions can increase the cost of a self-study course considerably.

c. Video Courses

- Video is one of the fastest growing methods of training large groups spread over several locations. The recent advances in technology and the ability to interact with microprocessors make the potential of video training tremendous.
- In field engineering, a majority of the information is technical, requiring that the producers of video courses be extremely knowledgeable about the equip-

ment taught, the functions involved in the jobs of an FE, and the video medium itself. This results in a large investment of time and money when putting together a training staff.

- There are very few independent companies specializing in video education for field engineering. Those that do specialize in video courses should be used not only to develop video courses but to assist in the development of in-house video departments.

- There are several other forms of media education. Unfortunately their uses are not as flexible as video. For example, audio-slide presentation is excellent for teaching large groups but one is limited to what can be shown on a slide.

  - Audio tapes are easy to carry and can be used in a variety of applications. However, with no visual capabilities, students have a difficult time retaining the information.

- Due to its growing popularity and potential impact, only video will be addressed.

i. Advantages

- The advantages of video far outnumber the disadvantages, as the following list indicates.

  - Video matches the entertainment media. Thus, students used to watching television are receptive to it.

  - Information is compressed 4:1, resulting in shorter classes.

  - Expenses are reduced by:

    - Less student time at the educational center.

- Eliminating travel completely in many cases.

- The quality of courses is consistent and can be updated very easily.

- New microprocessor systems allow video to interact with the student.

- Facility requirements can be stabilized.

- Training on discontinued products can be ongoing, with little or no impact on the field.

ii. Disadvantages

- The major disadvantage of video is the high front-end expense of equipment and staff personnel.

  - Video also requires a long development cycle - about 50 hours of development for one finished hour of video.

  - Video, like the self-study courses, is very difficult to manage in the field.

iii. Costs

- The cost of preparing a 20-day lecture course on video tape today averages approximately $175,000.

d. Computer Based Instruction

- Computer Based Instruction (CBI) has been used very effectively by both IBM and CDI (Control Data Institute) over the past several years. It not only has all the advantages of interactive self-study, it also handles many of the management functions which limit the self-study method.

i. Advantages

- The advantages of computer-based instruction courses are:

  - Time spent at the education center is reduced significantly.

  - Large numbers of students can be handled simultaneously.

  - Remedial education is already built into most systems.

  - Education schedules can be flexible because instructors and classrooms need not be scheduled.

  - Software education can be done totally from any location because the remote terminal will simulate any environment needed.

  - Most systems offer management tracking and automatic enrollment.

  - Courses can be corrected and updated at the central site quickly.

  - Student comments and questions can be monitored from the central site, allowing instructor-student interaction.

  - Measurement results are available at the central site to validate course results.

  - Tests and quizzes can be changed to eliminate cheating.

ii. Disadvantages

- The disadvantages of CBI are as follows:

  - Hardware system costs are high.

- A long development cycle is required - 100 hours of development to one hour of instruction.

- Students tire of communicating with a terminal.

- Lack of visuals prevents certain types of information from being effectively taught on terminals.

- System terminal networks are required.

iii. Costs

- The cost of CBI is extremely difficult to calculate.

  - If a terminal network is in place, then only course development and monitoring are required. However, if the purchase of a terminal network is necessary, the cost will obviously be significantly higher.

  - Companies who are not equipped to put a network in place still have the CBI option by using outside learning centers, such as those offered by CDI. These centers are located throughout the country and will also assist in course development.

- Regardless of resources, course development time must be considered as a primary cost item. Course development calculations are based on 100 hours of writing for a one-hour course. This would result in 16,000 hours of development, or 1,000 days, for a 20-day course. So, 16,000 hours divided by 160 hours per month equals 100 months, or over four man-years. This adds up to development costs of $224,000 at today's instructor salaries.

- At first glance, CBI seems to be extremely expensive. However, eight students in a lecture/lab course cost $14,880 in expenses alone. Therefore, the development costs of CBI are more than paid for after 16 classes.

- CBI also offers the potential for simulation of the electromechanical and fluid (dry or wet) processes found in manufacturing plants, in addition to its inherent ability to duplicate the digital processes of central computers and electronics.

    - In some cases, special purpose simulators have been built. They can be standalone training devices or units interfaced to a generalized CBI system.

    - With this capability, a technician can be trained to service an entire system.

8. ESCALATION PROCEDURES

- The term escalation procedure is used to describe the process by which a customer service problem "escalates" through a vendor's command hierarchy until it is resolved.

    - The largest companies (IBM, AT&T, DEC, etc.) usually have very rigid and tightly controlled escalation procedures.

    - Other firms have them, but they tend to be loosely defined and structured, leaving a great deal of decision-making in the hands of the on-site serviceperson.

- Every maintenance vendor surveyed has a formal escalation procedure in place. With epithets ranging from "alert" procedures to "early warning" procedures, all have common objectives.

    - Some procedures ensure, as tradition demands, that the account sales representatives are alerted to down machines and potential image problems before they or their managers are called by irate customers. This fundamental objective dates back to earlier times when field service managers were less confident in personally defusing potentially explosive situations.

- Some of the procedures are oriented toward direct access to technical assistance. Field engineers are required to discuss problems with branch or regional specialists after a checkpoint in elapsed time. The intermediate specialist is then required to involve a national or plant technical support specialist after a certain elapsed-time checkpoint.

- Other vendors structure escalation procedures along management lines following time and circumstance checkpoints, at which points increasing levels of management make judgements on the delegation of technical, hierarchical responsibilities and communications with the user's hierarchy.

- The more advanced escalation procedures involve checks and balances.

  . Technical hierarchy, field engineering management hierarchy and sales hierarchy all escalate through their own functional lines of communication. Cross talk at each level ensures that escalation occurs.

  . Daily "status reports" are wired or called into headquarters through the hierarchy, with negative or "no situations" forced to ensure that escalation channels are open each workday.

- With remote maintenance aids such as remote diagnostics, system support centers, etc. becoming more prevalent, strict adherence to formalized escalation procedures becomes a necessity if the process is to work at all.

9. SPARE PARTS

- With rising interest rates, computer vendors have become concerned over the cost of carrying spares inventories which may run as high as 40% of the basic cost of spares on an annual basis.

    - Third-party maintenance vendors and autonomous field service divisions who must expense their own carrying costs have become particularly affected and in many cases have reached a "pain threshold."

    - Rapidly changing technology and the shorter product life cycles (compared with earlier products) compound the problem by increasing the risk of obsolescence in carrying excess spares.

- The only "out" for the vendor is to transfer the cost of spares to the customer. This is being done with some frequency today and is definitely a future trend.

    - In this case, the customer pays up-front for spares and, in many instances, stocks them on-site.

IV AMMUNITION PLANT EPCS STATUS

IV AMMUNITION PLANT EPCS STATUS

A. GENERAL INFORMATION

- INPUT visited seven ammunition plants that had installed, or were planning to install, digital computers for controlling some of the production and/or process lines. These seven plants are generally representative of the types of ammunition plants in the U.S. Army ammunition production complex, as shown in Exhibit IV-1.

- The seven plants visited are owned by the U.S. Army but are operated by private contractors, (government owned, contractor operated (GOCO)).

- This section summarizes the information obtained from each plant. Specific conclusions and recommendations will be found in other sections of the report.

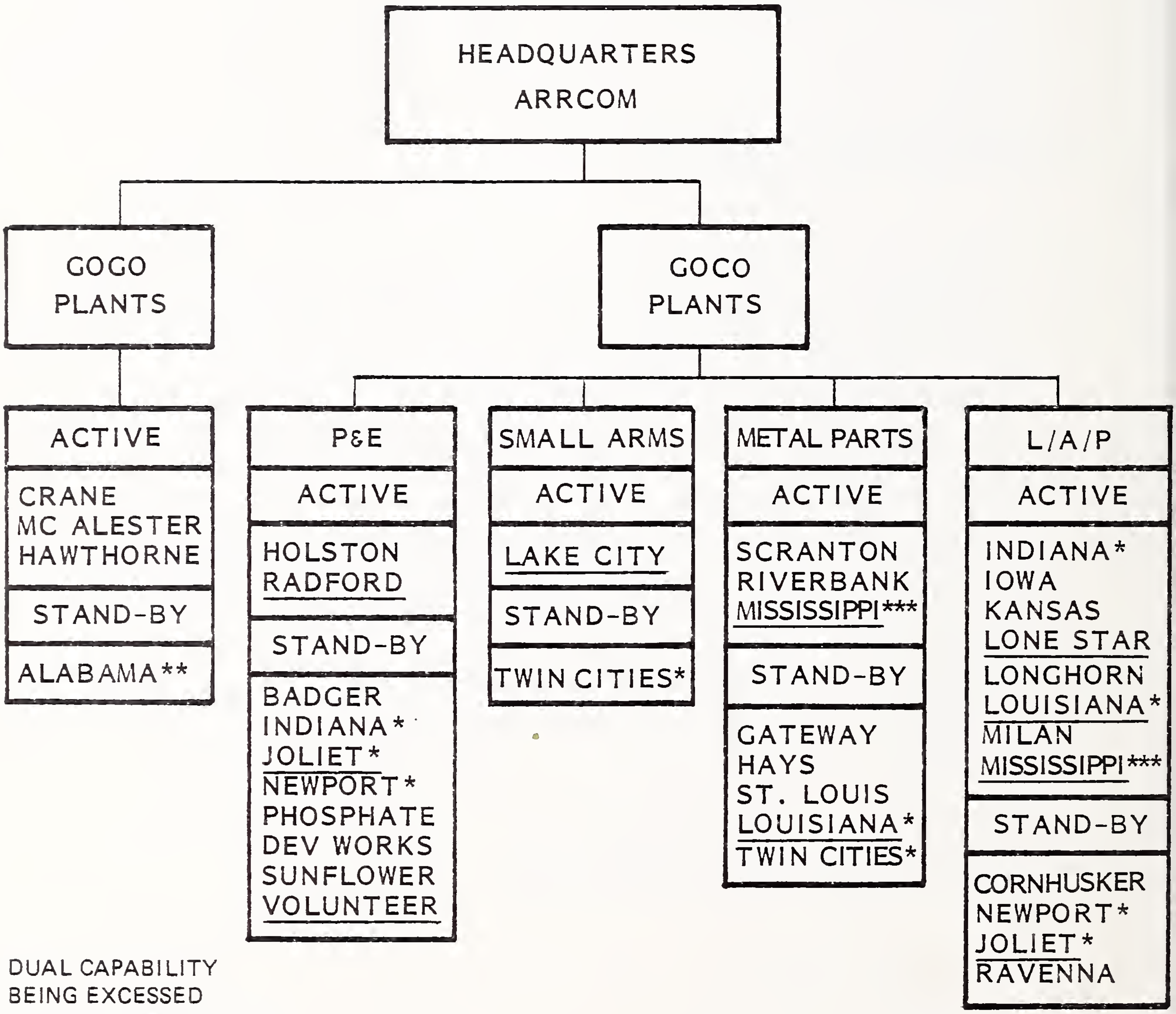
B. JOLIET ARMY AMMUNITION PLANT

1. PLANT DESCRIPTION

- The Joliet Army Ammunition Plant (JAAP) is devoted primarily to the production of trinitrotoluene (TNT) for use by other Army ammunition production facilities.

EXHIBIT IV-1

U.S. ARMY ARMAMENT MATERIEL
READINESS COMMAND



* DUAL CAPABILITY
** BEING EXCESSED
*** UNDER CONSTRUCTION
(DUAL CAPABILITY)
UNDERLINE - VISITED BY INPUT

  - A small portion of the complex loads, assembles and packs (LAP) 40mm ammunition.

  - Some dinitrotoluene (DNT) is also produced at this plant.

- There are 16 production lines at Joliet for TNT production.

  - Ten are batch production lines.

  - Six are CIL (Canadian Industries Ltd.) continuous process lines.

  - Three of the six are built to run under an electronic process control system utilizing direct digital control in a closed loop mode.

- JAAP is operated by Uniroyal for the U.S. Army.

2. ELECTRONIC PROCESS CONTROL SYSTEM DESCRIPTION

- The primary system designer for the electronically controlled portion of the lines is The Foxboro Company of Foxboro, Massachusetts.

  - The heart of the system is a Foxboro-designed PCP-88 system with analog and manual backup.

  - A Foxboro Spec 200 system, while not part of the production process, does monitor the alarms and will shut the system down safely in an emergency.

- The system was designed in 1972 to 1973 and accepted by the plant contractor and U.S. Army in 1975.

  - The specific Joliet design was done in 1972 to 1973, but the PCP-88 system for controlling continuous TNT production lines was designed in early 1970 for the Volunteer Army Ammunition Plant (VAAP). The Joliet system and Volunteer system are twins.

  - At Joliet only one line was tested even though the system was designed to handle three lines.

- Closed loop control is exercised by monitoring flow speeds, vat levels and agitation speeds. Valve positions are sensed and adjustments made if necessary.

  - There is no on-stream analysis for measuring chemical quality.

- The processors used by Foxboro in the PCP-88 system are PDP-8/Is built by Digital Equipment Corporation (DEC).

  - The other equipment in the control system was built by and/or integrated by Foxboro into the PCP-88 system. Exhibit IV-2 illustrates the principal components of this EPC system.

- The standard software for the system was supplied by DEC. The FOCUS operating system is used as a base.

  - Foxboro supplied its standard EPCS software and also supplied custom software where necessary. ICI Americas wrote the EPCS software specification.

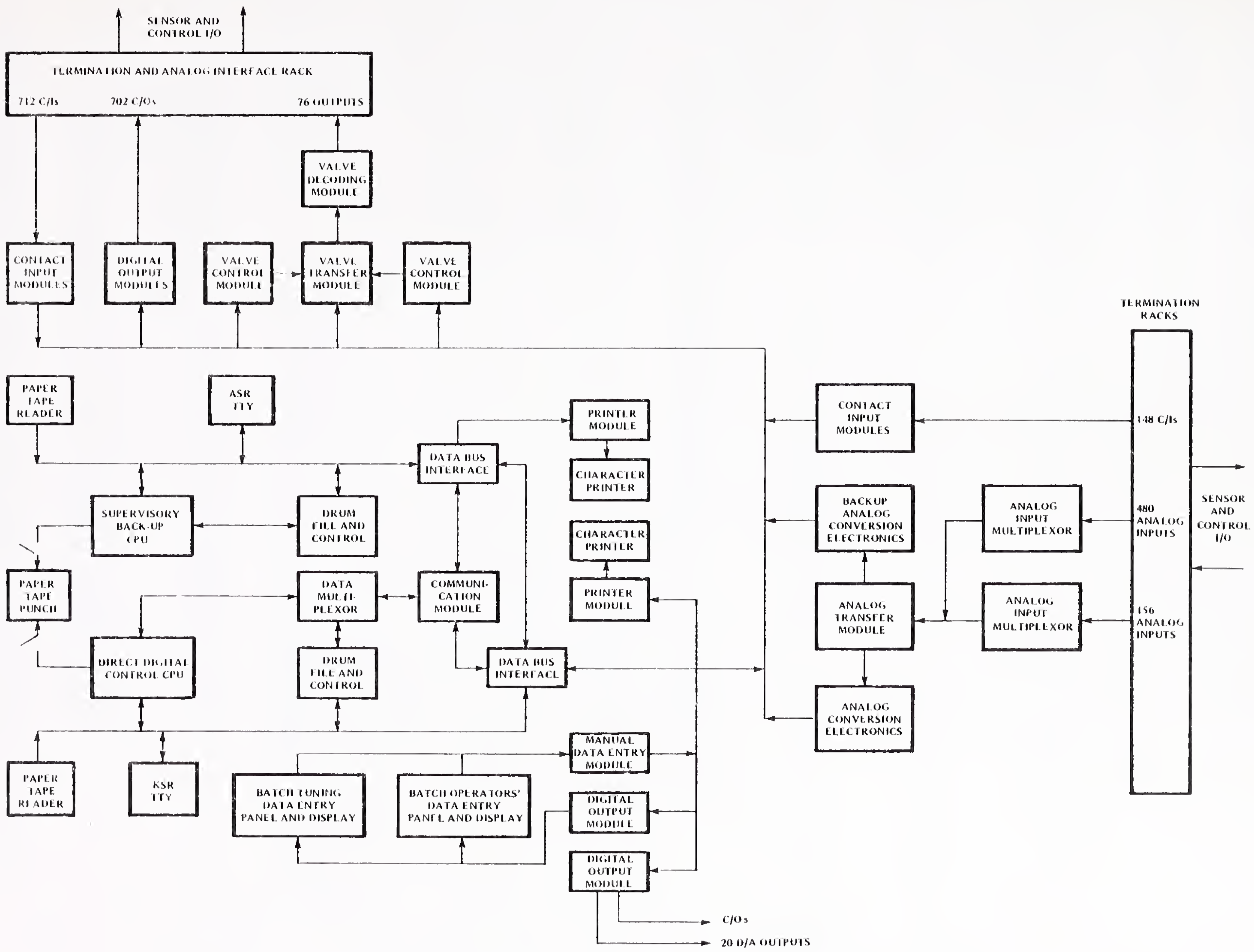
- Programs are stored on the drum. Backup, permanent storage for the programs is on mylar-coated paper tape.

- Hardware documentation is to the board level with some chip layouts detailed.

  - This documentation is up-to-date and complete by all industry standards.

EXHIBIT IV-2

SIMPLIFIED BLOCK DIAGRAM OF FOXBORO PCP-88 ELECTRONIC PROCESS CONTROL SYSTEM AS USED AT JOLIET AND VOLUNTEER ARMY AMMUNITION PLANTS



  - The documentation was not entirely complete prior to initiation of the MMT layaway program.

- Software documentation is complete.

- The operating environment and the layaway environment are the same.

  - The temperature is kept at about 70°F, and the humidity at 40% or less.

  - In summer, the air-conditioning cools the system down so completely that occasionally it must be reheated.

  - The air is electrostatically filtered.

- The computer room is an earth-protected, bunker-type building.

3. OPERATING EXPERIENCE

- Line 16, the EPC continuous process TNT production line, was operated for six months before being shut down.

  - The maximum production rate of 60 tons per day was reached after two days of running.

- The startup and operating experience on this line was very good during the six-month period.

  - A temperature converter had a bad potentiometer at startup time.

  - Some sensors froze during the wintertime, and they were changed to magnetic-flow meters.

- The system ran 24 hours per day. No maintenance plan was actually implemented during the operational period.

  - The Foxboro-recommended maintenance plan was available, but it wasn't used.

4. LAYAWAY AND REACTIVATION

- The Joliet Army Ammunition Plant has been one of the test sites used by ARRADCOM in examining the effects of various storage conditions on system reactivation.

  - For the three-year period, 1977-1980, JAAP was reactivated every six months.

- During the dormant period the electronic control system was shut off completely.

  - The proper environment was maintained in the computer room.

  - The magnetic drum was turned off, but the helium environment was maintained.

  - Those pneumatic controls that might have been under water were removed and stored in a controlled environment.

  - The 24V relay logic room was originally left alone, but the underground level became flooded once and the humid atmosphere caused problems. Since then a sump pump and dehumidifier have been used successfully.

  - Some electromechanical devices were stored off-line, and some in the 24V relay building.

  - Pumps left on-line were kept in a preservative.

- Software is kept on the magnetic drum and on oil-impregnated mylar tape.

  - The paper tapes are kept in the computer room. Another set is kept at JAAP in a vault, and a third set is at Foxboro.

  - The paper tapes at JAAP have been verified; the tapes at Foxboro have not been tested.

- Documentation is kept in the computer room in the controlled environment.

  - The hardware and software documentation also exist on microforms which are kept in the vaults.

- Reactivation testing of the system means testing computers, electronic controls, sensors, valves, etc. without the use of live chemicals.

  - Sensors are tested randomly with a goal of 10% of the total being tested.

  - Each control line is tested separately and every activator.

  - All computer peripherals are tested.

- The layaway and reactivation testing program at Joliet has been directed and funded through ARRADCOM, who has monitored and abetted all aspects of the program.

  - At the last reactivation test, an ARRADCOM-produced reactivation manual was also tested. This is an extremely detailed manual aimed at allowing relatively untrained but skilled personnel to activate the system.

  - The manual is an illustrated step-by-step guide to turning the system on. Each step is described and accompanied by photographs showing the cabinet in which the hardware necessary for the step is located; the specific switch, etc., is marked in yellow.

  - In addition, each page contains a schematic of the room, with locators indicating the position of the specific cabinet within a cabinet bank.

- A series of other user-oriented manuals for check-out, documentation, cross reference, indexing, systems overview, and systems description are underway as part of the ARRADCOM program.

- Overall, the reactivation experience during the three-year test period was very good with improvements made during each cycle.

  - At an early reactivation, a wire pit in the 24V relay building was flooded and the wires became grounded. The conduits were also flooded.

  - Turning the power on all at once resulted in a diode matrix blowing which is not a recurring problem.

  - All sensors are removed and 10% are tested and recalibrated each time the system is reactivated.

5. SPARE PARTS MANAGEMENT

- There is no spare parts management program at JAAP.

  - The spares on hand are basically the Foxboro-recommended spares.

  - They are, for the most part, in an environmentally controlled area.

  - The spares are not dated upon receipt and are not recycled when their shelf life is exceeded.

  - Spares are not tested when received and there have been failures when the spares have been plugged in.

- Parts listing down to the board level have been supplied by Foxboro.
  - The chips are from many sources and each is stamped with a descriptive number.
  - No list is kept of alternative sources of spare parts nor is there any program to obtain and test "compatible" spares.
  - Foxboro has been relied upon to provide the necessary spares, and its support has been very good.
- Foxboro has announced that it will not formally guarantee support of the spares program beyond December 1982.

6. PERSONNEL SKILLS PROGRAM

- There is no program to keep a cadre trained in the maintenance and operation of the EPC system, although there is a personnel resources program sponsored by ARRCOM which may resolve this issue.
  - Currently at JAAP, only one person is fully trained. He is training one other person.
  - In a maintenance mode it is very difficult to keep good people and to keep them motivated for extended periods of time. Fully trained, EPC people are in demand and will tend to find more interesting employment.
  - At JAAP, the maintenance force includes four electricians and four instrument mechanics. There are no electronic technicians for the system.
  - The documentation is in "ladder logic" form oriented toward the available technical skills.

- Training in both hardware and software has come from Foxboro. Some DEC classes have been attended for CPU training.

    - While some training aids have been produced for some of the lines, there is a minimal amount for the EPC lines, and training is of the OJT variety.

    - Training will be on an ad hoc basis, and difficulty is anticipated in attracting new people. Affirmative action programs tend to slow down the finding and training of new personnel.

- Trained personnel can be tracked within Uniroyal itself in case of an emergency, but there is no tracking of personnel who leave the company.

    - There is a difference of opinion as to whether or not personnel who have been removed from the system for six months or more will be able to get back "on board" in less time than it would take to train fresh people. Respondents from other organizations feel that the skills are never completely lost, and the basic understanding of the system is of prime importance.

7. FUTURE PLANS

- The problems of timely reactivation are recognized by the operating contractor.

    - There is concern over the termination of vendor support, of maintaining and repairing an obsolete system, of the lack of skilled personnel, and of the lack of training materials with which to train new personnel.

- The contractor has received some funding to begin addressing the problems that will mutually occur at other AAPs that are using Foxboro PCP-88s when Foxboro withdraws support in December 1982.

  - ARRCOM has requested that the three affected AAPs jointly prepare a recommendation. ARRADCOM is participating in this effort.

- Joliet itself is planning to follow with another reactivation in 12 months.

  - The reactivation testing program was prepared by ARRADCOM.

- At the time of the interview, the future was an unknown because no respondent knew how much money would be allocated, if any, for specific maintenance of the EPC line.

C. LAKE CITY ARMY AMMUNITION PLANT

1. PLANT DESCRIPTION

- The Lake City Army Ammunition Plant (LCAAP) is primarily a LAP plant that receives material from other plants for final assembly.

  - The plant was initially built in the early 1940s and is currently operated by Remington Arms Co., Inc. for the Army.

- In 1975-1976 a building was refurbished, and automated production lines were installed to perform the four functions of:

  - Case manufacture.

  - Bullet manufacture.

  - Primer insertion.

  - Load and assemble.

- Connecting all these operations is a sophisticated materials handling system that ends in a packing and palletizing operation.

- The automated production facilities were designed in 1969 but not installed for another five to six years.

    - Portions of the installation are still undergoing acceptance testing and prove-out.

- Nine different vendors are involved in the system design, fabrication, installation and equipment supply for all five automated functions, as shown in Exhibit IV-3.

2. ELECTRONIC PROCESS CONTROL SYSTEM DESCRIPTION

- There are four functional submodules in the manufacturing of 5.56mm ammunition.

    - Each submodule is made up of five production lines.

    - Each production line is controlled by its own processor, as shown in Exhibit IV-4.

a. Case, Bullet, Load and Assemble Submodules

- These three submodules contain fifteen production lines some of which are controlled by their own DEC PDP-11/05 computers.

    - The basic production machinery shown in Exhibits IV-5 through IV-7 consists of multiple rotary turrets connected by transport chains which carry material from one turret to the next. Each turret has 24 machining stations.

EXHIBIT IV-3

CONTRACTORS INVOLVED IN THE DEVELOPMENT OF THE AUTOMATED PRODUCTION FACILITY AT LCAAP

AUTOMATED FUNCTION	DESIGN AND FABRICATION CONTRACTOR	ELECTRONIC EQUIPMENT SUPPLIER
CASE MANUFACTURING	GULF AND WESTERN	DEC
BULLET MANUFACTURING	GULF AND WESTERN	DEC
LOAD AND ASSEMBLE	GULF AND WESTERN	DEC
PRIMER INSERT	FMC AUTOMATION	HONEYWELL
CASE MANUFACTURING INSPECTION	BATTELLE NORTHWEST	DATA GENERAL
LOAD AND ASSEMBLE INSPECTION	BATTELLE NORTHWEST	DATA GENERAL
MATERIAL HANDLING	RISI	SQUARE D
MANAGEMENT INFORMATION SYSTEM	SCIENCE APPLICATIONS	DEC

EXHIBIT IV-4

SIMPLIFIED FACTORY AUTOMATION LAYOUT AT LAKE CITY ARMY AMMUNITION PLANT

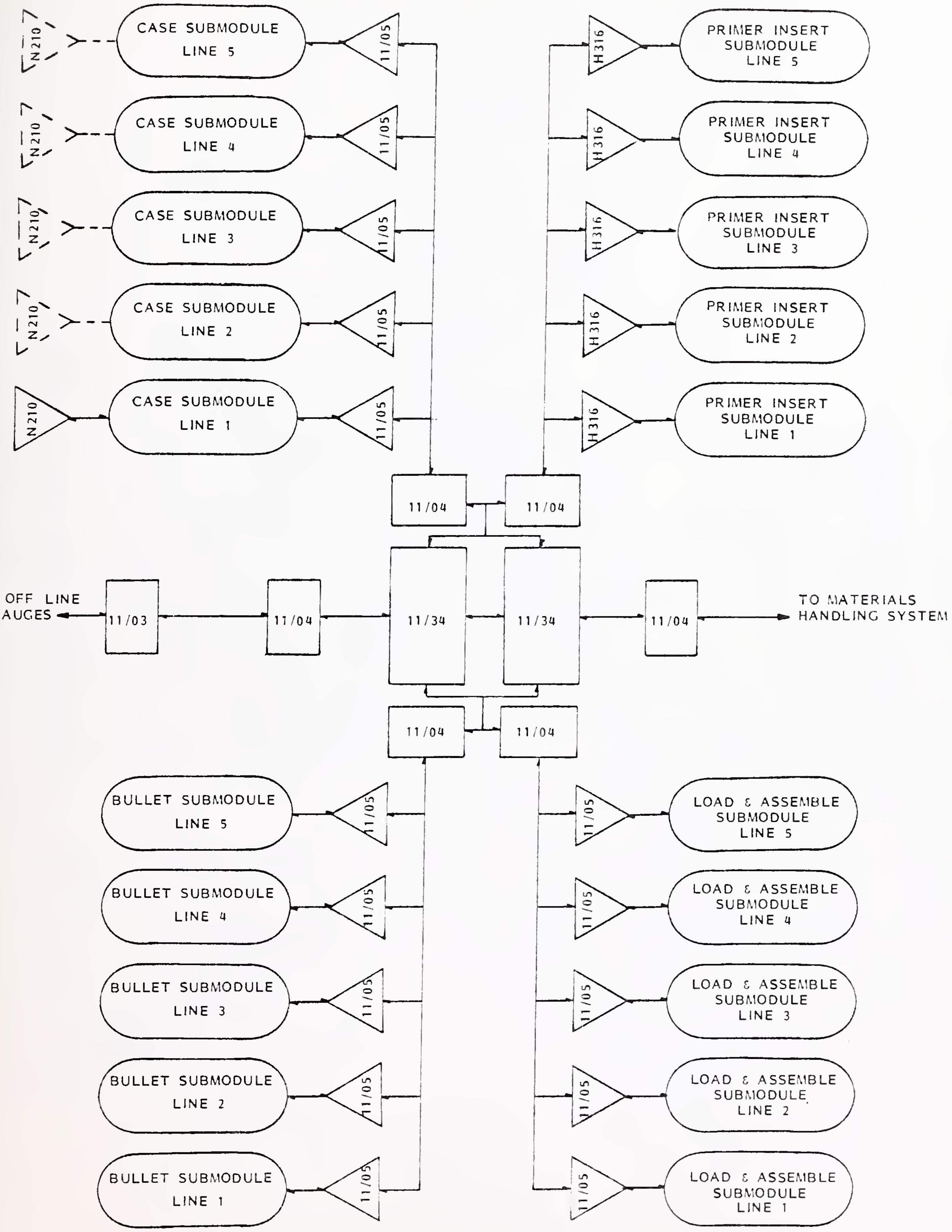
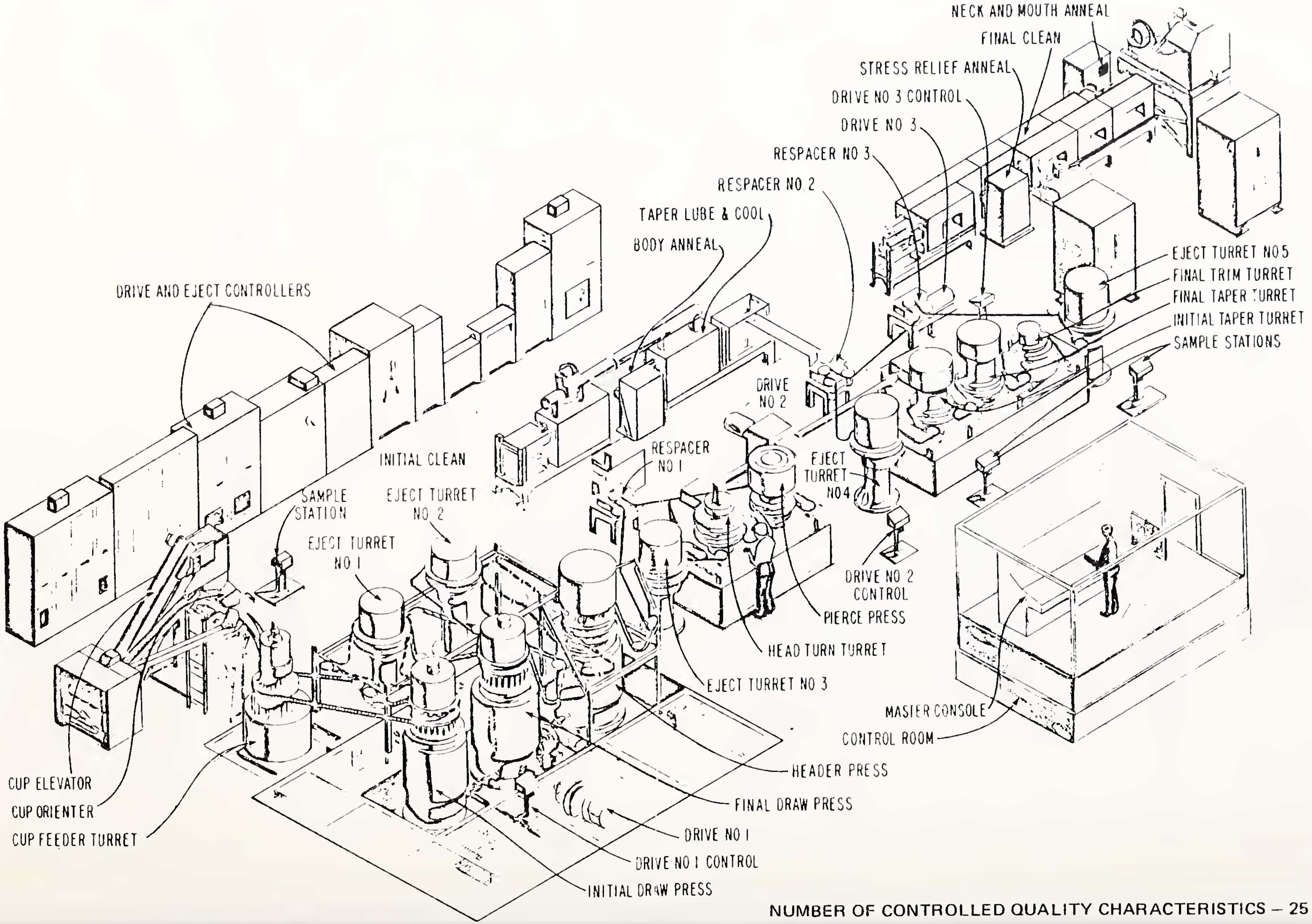

N210
CASE SUBMODULE LINE 5
CASE SUBMODULE LINE 4
CASE SUBMODULE LINE 3
CASE SUBMODULE LINE 2
CASE SUBMODULE LINE 1
11/05
H316
PRIMER INSERT SUBMODULE LINE 5
PRIMER INSERT SUBMODULE LINE 4
PRIMER INSERT SUBMODULE LINE 3
PRIMER INSERT SUBMODULE LINE 2
PRIMER INSERT SUBMODULE LINE 1
11/04
TO OFF LINE GAUGES
11/03
11/34
TO MATERIALS HANDLING SYSTEM
BULLET SUBMODULE LINE 5
BULLET SUBMODULE LINE 4
BULLET SUBMODULE LINE 3
BULLET SUBMODULE LINE 2
BULLET SUBMODULE LINE 1
LOAD & ASSEMBLE SUBMODULE LINE 5
LOAD & ASSEMBLE SUBMODULE LINE 4
LOAD & ASSEMBLE SUBMODULE LINE 3
LOAD & ASSEMBLE SUBMODULE LINE 2
LOAD & ASSEMBLE SUBMODULE LINE 1

EXHIBIT IV-5

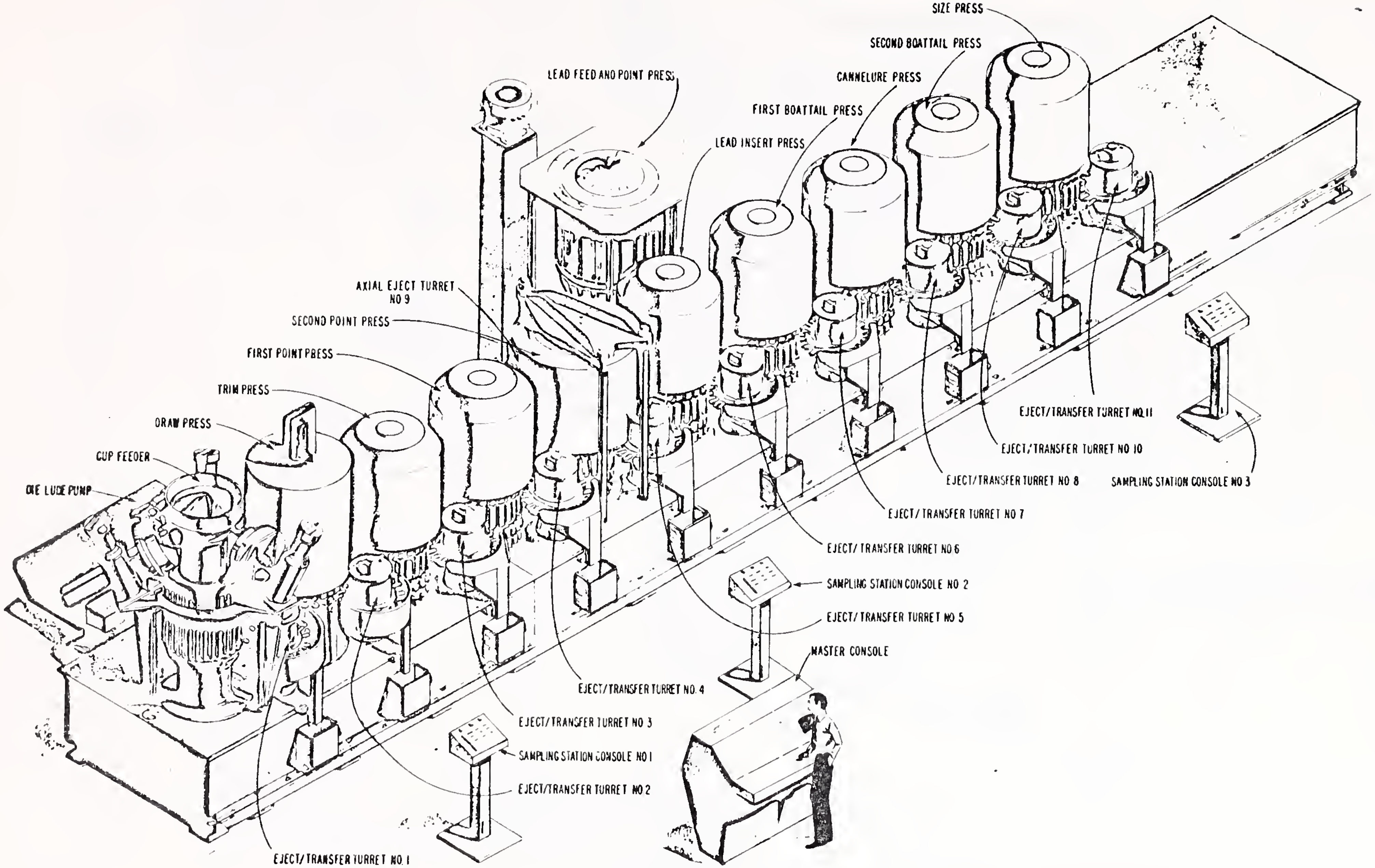
5.56mm CASE SUB-MODULE



NUMBER OF CONTROLLED QUALITY CHARACTERISTICS – 25

EXHIBIT IV-6

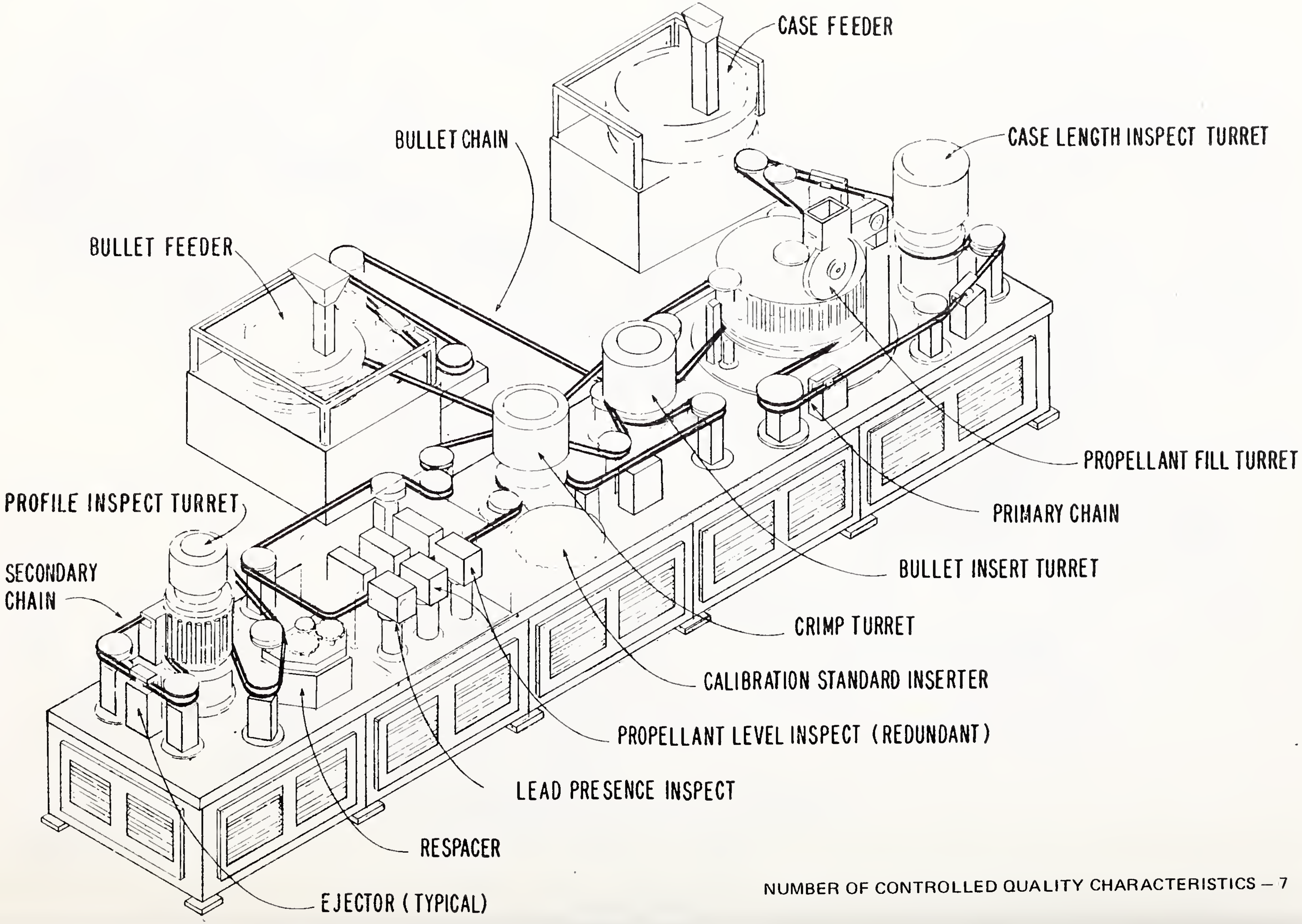
BULLET SUB-MODULE "A" (BALL)


SIZE PRESS
SECOND BOATTAIL PRESS
CANNELURE PRESS
FIRST BOATTAIL PRESS
LEAD INSERT PRESS
LEAD FEED AND POINT PRESS
AXIAL EJECT TURRET NO 9
SECOND POINT PRESS
FIRST POINT PRESS
TRIM PRESS
DRAW PRESS
CUP FEEDER
DIE LUBE PUMP
EJECT/TRANSFER TURRET NO 11
EJECT/TRANSFER TURRET NO 10
EJECT/TRANSFER TURRET NO 8
SAMPLING STATION CONSOLE NO 3
EJECT/TRANSFER TURRET NO 7
EJECT/TRANSFER TURRET NO 6
SAMPLING STATION CONSOLE NO 2
EJECT/TRANSFER TURRET NO 5
MASTER CONSOLE
EJECT/TRANSFER TURRET NO. 4
EJECT/TRANSFER TURRET NO 3
SAMPLING STATION CONSOLE NO 1
EJECT/TRANSFER TURRET NO 2
EJECT/TRANSFER TURRET NO 1

NUMBER OF CONTROLLED QUALITY CHARACTERISTICS – 30

EXHIBIT IV-7

LOAD AND ASSEMBLE SUB-MODULE



NUMBER OF CONTROLLED QUALITY CHARACTERISTICS — 7

- The PDP-11/05 controls and monitors the production and ejection of parts-in, parts-out, and ejects by tool stations.

    - The information is displayed on video terminals.

- The computer program models the physical operation of the machine.

    - Two DEC operating systems are used: CAP-11 (cassette programming system) and RT-11 (single user on-line program development system).

    - Applications are programmed primarily in assembly language.

b. Primer Insert Submodules

- Each production line within the submodule shown in Exhibit IV-8 is monitored and controlled by a Honeywell H316 computer.

    - The computer keeps track of all cases in the machine, records and stores data from the inspection devices, and rejects or unloads the cases based upon the inspection data.

- The DAP16 operating system is used, and major portions of the application are programmed in assembly language.

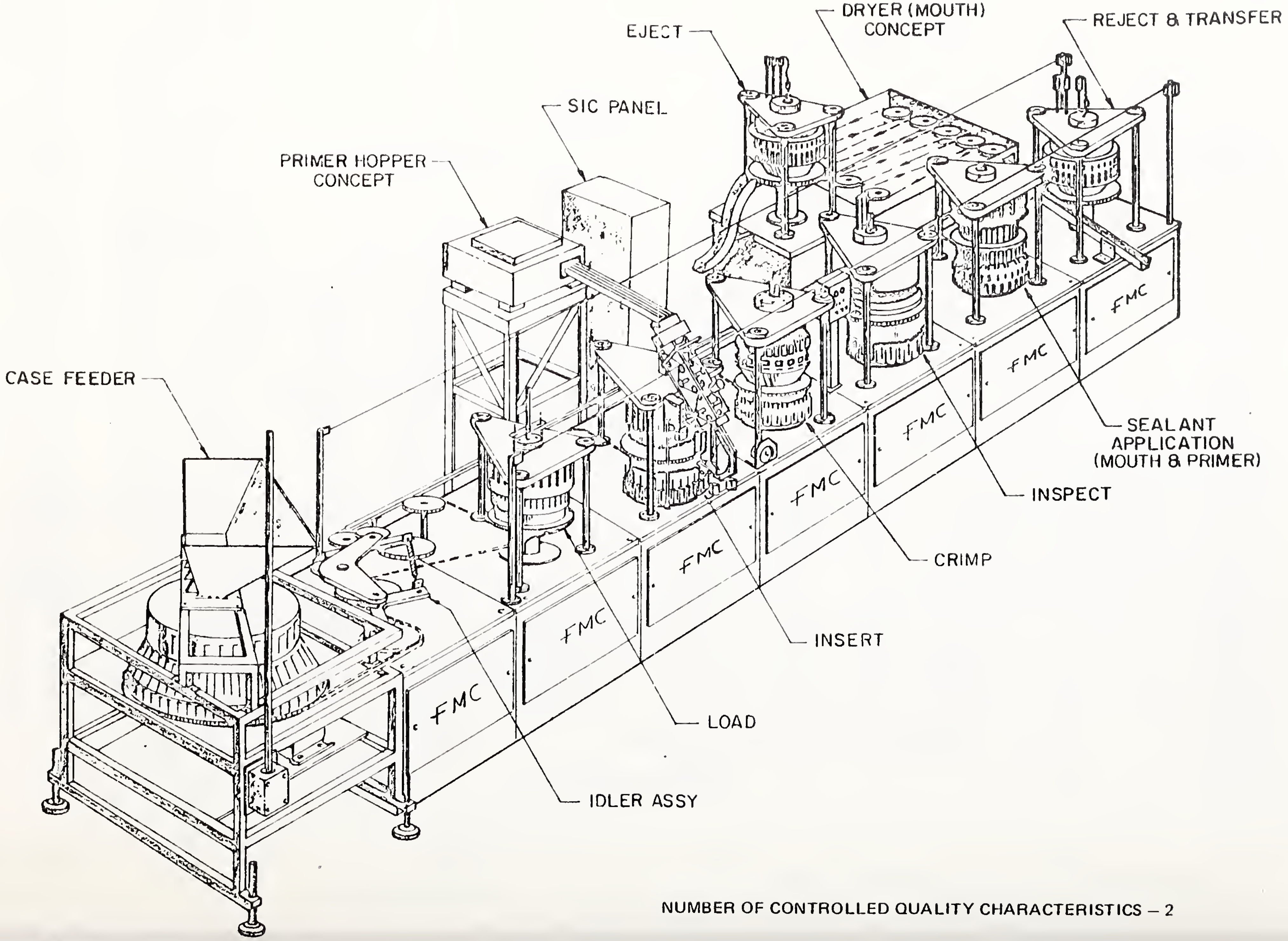
c. Automated Material Handling System

- This system transports production components and materials between submodules. The system also provides for a 10-hour production accumulation of completed components between submodules. Finished goods are transported to the packing operation for boxing, palletizing, marking and strapping.

    - These transport operations are controlled by Square D programmable logic controllers with a manual backup system in case of malfunction.

EXHIBIT IV-8

5.56mm PRIMER INSERT SUB-MODULE



NUMBER OF CONTROLLED QUALITY CHARACTERISTICS – 2

- Each controller consists of a processor, I/O racks and a data terminal.

- The units are programmed in BASIC Language. For timing and counting, programming is done through the math/logic unit.

d. Cartridge Case Measurement and Eject System

- This system, consisting of a mechanical case handler and measuring instruments controlled by a Data General Nova 210, inspects cases received from the case submodule and rejects or accepts them based upon the measurements.

  - The measuring instruments are located throughout the handler path, and the computer keeps a running tally of the data and sends reject signals to the handler for air reject of unacceptable cases.

  - The operating system is Data General's RDOS. Applications are programmed in assembly language, FORTRAN and extended BASIC.

- Only one of the five computers is currently installed as a prototype. If the tests are positive, and as of this writing they are, then the full system will be installed.

e. Management Information System

- The management information system (MIS) is a central data acquisition, data processing, control and communication system that is designed to coordinate data from the production submodules, the inspection system, and the materials handling system.

  - The system acquires production data, directs that process samples be taken, and determines from this data if production is under control.

  - Management information, inventory information, and production data are reported upon request.

- Two DEC PDP-11/34s serve as host computers, and six PDP-11/04s preprocess the data received from the other systems.
  - The peripherals consist of two disk drives, one line printer, one card reader, one magnetic tape drive, and several CRT terminals scattered throughout the building.
  - The following DEC software is used:
    - RSX-11M, a multitasking process control system.
    - DECNET, a communications operating system.
    - MCP, a multiprocessing control program.
- This MIS system is currently installed and going through checkout.
- Each of the production lines has an environmentally monitored control room which contains the computer systems and all other possible electronics.
  - The MIS system has its own centralized, environmentally controlled room.
- The documentation is not kept up-to-date by the vendors.
  - DEC documentation is the most up-to-date (hardware and software).
  - Any documentation gaps at LAAP are currently being addressed in the MMT layaway study.

3. OPERATING EXPERIENCE

- Each production line is capable of producing 1,200 shells per minute.

  - This potential has been achieved, and the line has averaged about 1,000 shells per minute.

- At this point only one line in each submodule is operating. All the systems are undergoing, or have undergone, prove-out of one phase or another.

- The systems are running with about 20% downtime per month (August and September 1980) which is an improvement over the 24% experienced in July 1980.

  - The problems on the production lines have been mechanical.

- Downtime due to computer or electronic malfunction has been very minimal.

  - Specifically, in September 1980 the lines were never down due to computer failures and were down only eight times due to electronic failures.

- This MIS system has turned out very detailed reports summing all the failures, mean time to repair (MTTR), mean time between failures (MTBF), etc. for management use.

  - The information is used to monitor and improve the reliability of the various components.

  - Minimal attention has been paid to these reports by management primarily because the system is in prove-out, and it is very difficult to separate startup problems from design flaws.

  - Management is concerned with the low overall uptime experienced and has taken steps to try to improve the situation.

- The MTBF for the various submodules ranged from 6 minutes to 44 minutes during September 1980.

-	Case submodule	-	6 minutes
-	Bullet submodule	-	12 minutes
-	Primer insert submodule	-	23 minutes
-	Cartridge case measurement eject system	-	27 minutes
-	Load and assemble submodule	-	44 minutes

- Preventive maintenance (PM) plans have been modified in an attempt to reduce downtime.
  - All systems receive PM daily.
  - Before starting operations in the morning, one hour of PM takes place. In the afternoon the systems undergo one-half hour of PM.
- The production lines can operate with 18 of the 24 stations on each turret operating. If more than six stations on a turret are down, then the whole line is brought down.

4. LAYAWAY AND REACTIVATION

- Four production lines are in layaway at the present time. They have never been in operation.
  - The electronics are being cycled because it is felt that they may deteriorate if not heated up. There is no evidence that this is so; just a feeling that electronic cycling will prevent surface corrosion on pins, sockets, and other metallic surfaces.

INF

    - Each production line is cycled twice each month provided there are enough parts so that it can operate. At one cycling during the month, product is moved through the line.

    - The reactivation cycle is to be drawn out to monthly, then quarterly, and, perhaps, if the systems respond well, the cycle may be stretched to annually.

- Sensors and other line I/O devices are left in place.

- The computers that are in an environmentally controlled area are kept under the same temperature and humidity conditions.

5. SPARE PARTS MANAGEMENT

- An inventory control group will maintain lists of vendors and spares.

    - The vendor list will not go to the component level nor will parts lists detail all the components.

- Mechanical spares are coated with cosmoline to prevent corrosion.

- Electronic spares are kept in an air-conditioned room by accident. It is not planned to keep spare parts in a controlled environment.

- Lists of alternative sources of spares are maintained, and it is planned to test compatible spare parts.

- Spare parts have been obtained from the other production lines in order to keep the operating line functioning.

    - The other lines are left inoperable for a period of time and may not be operable at any given time.

6. PERSONNEL SKILLS PROGRAM

- Turnover of personnel has been very low in the EPC systems area.
    - This is attributed to the newness of the system and the challenge of getting it all to operate.
    - Mechanical technicians are attracted from within the plant because working on and with the automated production line is exciting.
- A general electronics background that can be obtained in the military or in school is sufficient for a beginning.
    - Remington Arms feels it takes about one year to fully train an electronics technician in the EPC system.
    - Vendor schools and OJT are the primary training programs used.
- After the line is proved-out and production ceases, Remington Arms will have to face a different type of personnel problem - not one of training but one of personnel retention.

7. FUTURE PLANS

- As of October, 1980, funds have been requested to test various layaway procedures and cycling.
- It has been proposed that moisture-proof hutments be built around the equipment and the submodules, that desiccants be placed in the control room, and that all this could be sealed and left shut for ten years.
    - Hutments are collections of huts or an encampment.

  - LCAAP has stored electric motors for ten years in the normal standard environment with no apparent harm.

  - If the hutment turns out to be impractical, then the equipment will probably have to be recycled during the layaway period.

- The ARRADCOM program is addressing user-oriented manuals in the bullet and case lines. Further investigation is needed to establish a final layaway plan.

8. MISCELLANEOUS

- As long as Remington Arms has a production contract for 5.56mm ammunition, each of the five lines can be activated cyclically to produce live products.

  - This, of course, means the idle lines shouldn't be used to provide spares for the active line.

D. LONE STAR ARMY AMMUNITION PLANT

1. PLANT DESCRIPTION

- The Lone Star Army Ammunition Plant (LSAAP), operated by Day & Zimmerman, Inc., is a LAP GOCO plant that can produce monthly on a single shift:

- 3,800,000	- Artillery primers
- 15,000,000	- Detonators and lead assemblies
- 854,700	- Mortar and artillery fuses
- 630,000	- Grenades

63,000	M72 light antitank weapons
325,000	Artillery shells
136,000	Mortar shells
800,000	Supplementary charges

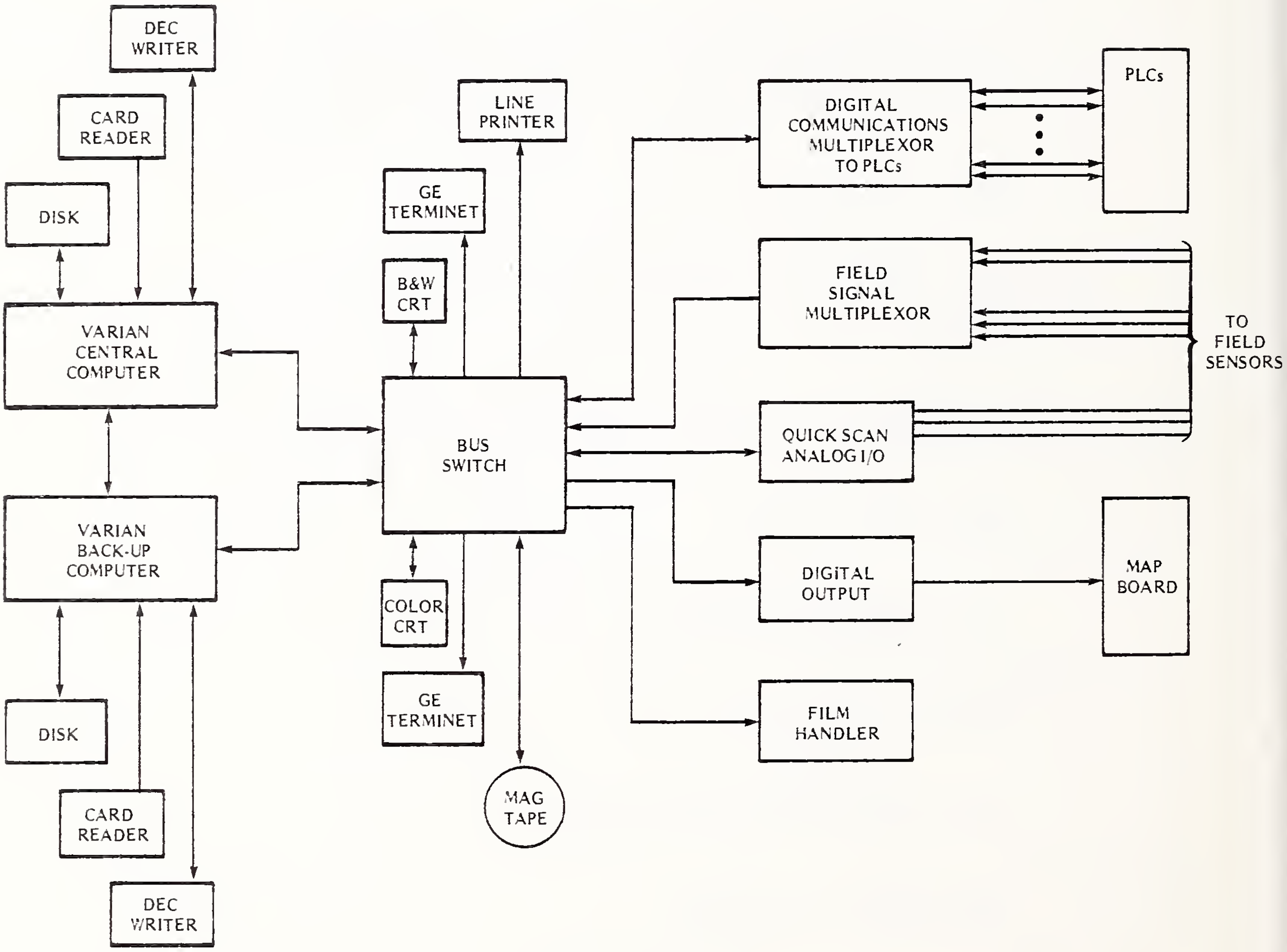
- The plant was constructed during 1941-1942 with 14 production lines.
  - During Vietnam the plant produced 127 different items using 12,000 people.
  - LSAAP is a currently active plant with a workforce of about 2,000 and minimal production contracts.
- Many of the production lines have undergone some modernization, and most lines use programmable logic controllers (PLCs) for some level of automatic local control.
  - Two lines are in the process of being computerized.
    - The E line for the LAP functions on 105mm ammunition.
    - The P line for the production of detonators.
- E line design began in 1974, installation started in 1976 and is still continuing.
  - P line design began in 1975 with installation starting in 1976.
  - PLC installations began as early as 1972.

2. ELECTRONIC PROCESS CONTROL SYSTEM DESCRIPTION

- The computerized E line receives shells from other plants, processes powder, loads the powder into the shell, then loads the detonator and assembles the other parts to make a complete projectile.
  - MRC, Inc. designed the turnkey system and is currently doing the installing.
  - MRC selected a Taylor Instruments control system which is based upon a Varian computer system (division of Sperry Univac).
  - Most of the PLCs are made by Allen-Bradley.
- The E line control system shown in Exhibit IV-9 uses a dual computer system consisting of:
  - Two CPUs.
  - Two 14" disk drives.
  - Two diagnostic consoles.
  - Two CRT displays.
  - Two teletypewriter (TTY) printers.
  - One magnetic tape drive.
  - One line printer.
- The computer monitors and controls about 600 I/O lines.

EXHIBIT IV-9

SIMPLIFIED E-LINE COMPUTER CONTROL SYSTEM AT LONE STAR ARMY AMMUNITION PLANT



- There is an extensive materials handling system to move the parts from one production area to the next.

  - The measuring devices at the end of the I/O lines include:

    - Pressure transducers.

    - Infrared temperature sensors.

    - Differential pressure gauges.

    - Pneumatic transducers.

- E line software is primarily FORTRAN (MRC and Taylor) with some Varian assembly language used for the basic Taylor programs.

  - MRC also uses its own program design language called ASTRAN.

- E line software is the total responsibility of MRC and is considered adequate.

  - Disk, cards and magnetic tape are used for program storage. The card decks cannot be updated because there is no card punch in the configuration. Program updates must come from MRC.

- All documentation for the E line is through MRC, and the hardware documentation is checked to the board level.

- The manufacture of detonators on the P line is controlled by a Modcomp II computer system designed and installed as a turnkey package by Computer Sciences Corporation.

  - The configuration consists of a single CPU, a disk drive, a TTY, and two CRT displays.

  - There are several PLCs on the line also.

- There are about 120 I/O points on the P line connected to either the computer or the PLCs.

  - The sensors connected to the computer are thermocouples and hi-lo limit switches.

  - Load cells are generally connected to the PLCs.

- The Foxboro Company is the primary instrumentation supplier on the P line.

  - Foxboro has provided documentation to the component level.

- Software is stored on the disk drive.

  - Software for the P line has had many problems, especially interfacing with the PLCs. In general, this software is currently considered less than adequate (November 1980).

- It is planned to keep both computer systems in controlled environments; however, that hasn't been fully achieved yet.

  - The E line computer room is earth-banked and has a controlled environment.

  - The P line computer system environment is being upgraded to meet "computer system standards." Currently, the humidity is controlled to some extent and the air is filtered through the cabinets.

  - An environmentally controlled system separate from the building's system is necessary.

3. OPERATING EXPERIENCE

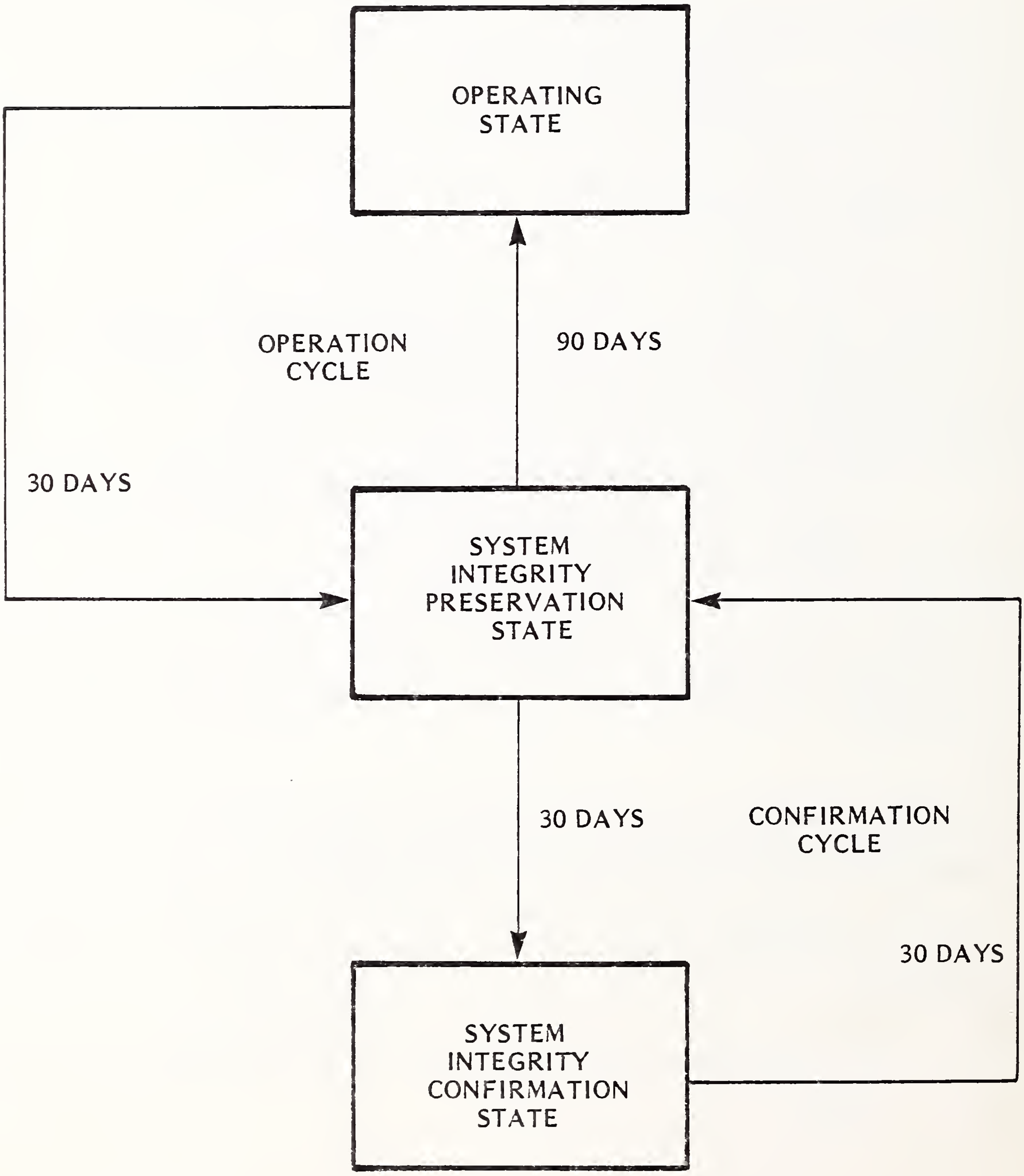
- There has been no operating experience with either line since both are still under construction.
    - The maximum production potential of the E line is one million projectiles per month working three shifts and seven days per week.
- Currently there is no preventive maintenance plan.
    - Maintenance will be done on an "as needed" basis.

4. LAYAWAY AND REACTIVATION

- An extensive layaway definitions and procedures manual is being prepared. Since it was incomplete and unapproved when scanned in November 1980, no comments can be made concerning its viability.
    - The plan is based upon a detailed definition of the possible states of the system and the procedures to move from one state to another within a set of rules (time allotted, etc.).
- Exhibit IV-10 shows the three states - operating, preservation (dormancy), confirmation (testing) - and the time allotted for changing the state of the system.
- Within this broad framework, a hierarchical documentation structure can be built that could extend down to the smallest component.
- Since the production system is under construction at present, it is in a form of layaway.
    - The materials handling system was idle and becoming rusty in many places.

EXHIBIT IV-10

PLANNED LAYAWAY AND REACTIVATION CYCLES AT LSAAP



  - Other idle equipment appeared to be left in place with no effort made to inhibit corrosion.

- It is felt that the computer systems should be left running in order to prevent deterioration.

- No reactivation has taken place since no activation has taken place.

5. SPARE PARTS MANAGEMENT

- There are detailed parts listings for both the E&P lines.

- Vendor listings are not complete nor are alternative sources of parts.

  - Spares are purchased from the manufacturer directly.

- Spares for the PLCs are in good supply, but there are few computer parts in stock.

  - After the systems are operational, spares will be purchased in accordance with both the vendors' recommendations and fiscal regulations.

- Currently there is no testing program for spare parts and no dating program for incoming spares.

  - Day & Zimmerman would like to do its own maintenance on the system, down to repairing boards if necessary.

6. PERSONNEL SKILLS PROGRAM

- For the E line, Day & Zimmerman has trained people generally, but the installation has taken so long that attrition has given the contractor some concern.

  - Day & Zimmerman is looking toward establishing its own internal training activity.

- For the P line, since it has been idle, there are no trained D&Z personnel in either hardware or software.
  - An in-house training function would aid this situation.

- D&Z likes to recruit people from technical schools with four-year degrees.
  - D&Z tries to recruit systems people not design engineers.
  - Right now D&Z feels it has fancy equipment that no one knows how to use.

7. FUTURE PLANS

- The prime objective is to finish both lines, have them prove-out, and then become productive.

- Another important objective is to complete the hardware and software documentation for both lines.
  - The documentation must be accurate, up-to-date, and complete.
  - A plan must be implemented for keeping the documentation up-to-date.
  - These are the goals of the ARRADCOM program.

- The layaway document must be completed, approved, funded and implemented.
  - It is an inclusive document that deals with all the electronics associated with the modernized lines including:

- Closed circuit TV systems.
- Fire protection systems.
- Materials handling equipment control systems.
- Power systems.
- Process machines control systems.
- Security systems.
- Telephone systems.

- ARRADCOM is planning implementation efforts similar to those being done at VAAP toward solving this problem.

8. MISCELLANEOUS

- The layaway plan seemed to be complete in that it wasn't limited to just the EPC system but included all other electronic systems in the modernized plant.

- A scanning of the plan indicated that it was very detailed for equipment and will approach software in a similar fashion, but seemed not to be concerned with the personnel problems during layaway.

E. LOUISIANA ARMY AMMUNITION PLANT

1. PLANT DESCRIPTION

- The Louisiana Army Ammunition Plant (LAAP) is a metal parts machining plant. The parts are sent to other plants for LAP operations.

- The overall plant was built in 1939.
    - Installation of the automated machining lines began in 1976 and is still going on.
- There are two automated lines in the plant. The Y line produces 105mm casings, and the M-4 line produces the ogives.
    - Neither of these lines has any centralized control system.
    - Both lines are automated using PLCs that were made by 14 different vendors.
- LAAP is operated by the Thiokol Corporation for the U.S. Army.

2. ELECTRONIC PROCESS CONTROL SYSTEM DESCRIPTION

- The Y line is automated with 14 different electronic PLCs made by 10 different manufacturers, as shown in Exhibit IV-11.
    - The A-B 7360s and the A-B 1774 are complex PLCs and are very close to being computers.
- Even though this is a highly automated line, people are needed to help at virtually all workstations.
- The entire line, since it is still being installed, has never been run, but part of each individual operation has been tested.
- The primary sensors connected to all the PLCs are limit switches.
    - There are some contact relays in the various systems especially for controlling the material handling subsystem.

EXHIBIT IV-11

LAAP Y-LINE ELECTRONIC CONTROL SYSTEMS

- GE LOGITROL - FORGE
- MODICON 284 - BAND WELDERS
- ALLEN-BRADLEY 1774 PLC - RISI MATERIALS HANDLING SYSTEM
- ALLEN-BRADLEY 1772 PLC-2 - J&L FINISH TURNING
- ALLEN-BRADLEY 7360 - J&L OGIVE
- ALLEN-BRADLEY 7360 W/PAL OPTION-OLLOFSON BASE MACHINES
- TEXAS INSTRUMENTS 5II SERIES - HARDNESS TESTER
- MODICON 484 - MAGNAFLUX TESTERS
- RELIANCE AUTOMATE 31 - THREADING MACHINE CONTROL
- AEROTECH SMART 1 - THREADING TOOLING CONTROL
- AMF VERSATRAN MODEL 600 - ROBOTS ON SLOTTERS AND ON J&L OGIVE
- MARPOS #2000 CONTROL - AUTOMATIC GAUGE
- MARPOS #4000 CONTROL - AUTOMATIC GAUGE
- SQUARE D LOGIC CONTROLLOR - M-107 NOSE PRESS

- Hardware documentation is available to the board level, but personnel on board currently can troubleshoot down to the component level.

- There is very little "standard" software for the PLCs. Each PLC is custom programmed by the vendor for its particular function.

- Programs are retained in the PLC itself.

  - With certain PLCs the programs can be stored on magnetic tape cassettes.

  - Paper tape can be used for program storage with a particular PLC if necessary.

  - Those PLCs that have UV erasable EPROMS have proven tedious to reprogram. The industry is moving away from such PROMS.

- The PLCs are designed to operate in an uncontrolled factory environment.

  - The temperature in the plant ranges from below 20°F in winter to up to about 140°F in the summer.

  - The humidity is uncontrolled, as is noise, vibration, particulate matter, etc.

- The same temperature and humidity conditions will exist when the system is in a dormant state.

  - Most of the system can be considered in dormant storage now since it is not operating and is in the same position as it would be under layaway.

3. OPERATING EXPERIENCE

- The production line hasn't been operated yet.

- There are no plans for methodically recording all failures and using the data for systems improvement or spares management.

- The overall maintenance plan is to follow strictly the advice of each individual vendor.

- However, the ARRADCOM MMT plan is to develop a Defect and Failure Reporting procedure to be used by all EPC facilities.

4. LAYAWAY AND REACTIVATION

- There is no reactivation history with this system yet, since it has never been operational.

- However, certain operations have been producing for a while.

  - When they are shut down for two to four months, the PLCs are cycled once each week.

- In general, the PLCs would be laid away in place or according to the manufacturer's advice. The ARRADCOM MMT plan implementation would positively impact this trend.

  - There is the possibility of removing the circuit boards from the PLCs and storing them for long periods in a controlled environment, but no definite plans along these lines exist. There is some concern that unless this were done in a well planned manner, mixups would occur.

- The materials handling PLCs would be stored in a controlled environment.

- Moisture problems are anticipated with the limit switches, but there are no plans to avoid the potential problems.

  - This was reported to INPUT.

- Cassette tapes with programs are stored in a normal office environment.
  - Some PLCs are remotely loaded and have self-diagnostics built in.
  - LAAP is trying to justify the buying of automatic loaders for the PLCs.
- All documentation is on plain paper and is kept in a normal office environment.
- The ARRADCOM plan will impact these areas requiring the problems to be addressed.

5. SPARE PARTS MANAGEMENT

- Spares are stocked according to the vendor's suggested list.
- There is no detailed listing of the parts vendors.
  - There is no list of alternative sources for parts.
  - There is no testing of spares because there is no equipment for testing them.
- Vendor support has been good. Turnaround time on board repairs is also satisfactory.
  - These repairs were generally done by local distributors of the vendor.
  - Other sources of board repair have been located and successfully used.
- Spare parts are usually left in the original wrapping and stored in the factory environment.

6. PERSONNEL SKILLS PROGRAM

- After the initial training which is to be provided by the vendor, the contractor is planning to train all new people.
    - Vendors have delivered training vans to the site for initially training contractor personnel.
    - An outside training company has been used for training on the more complex PLCs.
- The systems can be operated and maintained by an industrial plant electrician or a person trained in microprocessors.
    - With the assistance of the contractor, two local trade schools offer courses in industrial instrumentation and some students are expected to become employees.
- Reactivation should be fairly easy for a technician with some electronic background.
    - If something goes wrong, more experienced people must be available.
- Experienced people from LAAP, who may have moved on to other jobs with the contractor, can generally be traced if necessary.
- Currently, there is no problem attracting trainable people from the schools and through employment ads.
    - The South is a growing area, and as new industry moves in, competition will drive pay scales up. The contractor is concerned about his ability to meet the competition.

7. FUTURE PLANS

- The prime concern is getting the line running, and all resources are being devoted to that goal.
  - Some thought has been given to layaway concerns, but no plan for the electronic equipment is available other than to leave it in place.
  - The contractor would like to have funds to obtain a complete set of spares, a good dating and numbering system for the spares, and a controlled environment for storing them.

8. MISCELLANEOUS

- There is some thought that if the prime goal is to maximize production in the minimum amount of time, then the production line should be simplified.
  - The line should be broken into thousands of very simple jobs so that thousands of people can be quickly trained to perform the functions safely.

F. MISSISSIPPI ARMY AMMUNITION PLANT

1. PLANT DESCRIPTION

- The Mississippi Army Ammunition Plant, operated by Mason-Chamberlin for the U.S. Army, is currently under construction.
  - Mason-Chamberlin offices are in a shopping mall where the construction is supervised.
- The plant will be a complete manufacturing facility.

  - Facilities for the machining of metal parts and for LAP operations will exist at the site.

- Several vendors of electronic control equipment have already been selected, and other proposals are being evaluated. Computers and PLCs will be used in the plant.

  - A separate Westinghouse computer system will control each of two forge systems.

  - Allen-Bradley controllers will run the turning centers.

  - The LAP functions will be computer-controlled and are out for bids.

- The plant will make 155mm ammunition.

  - The forge area is the first portion to be built. This area will do shell forging and machining.

2. ELECTRONIC PROCESS CONTROL SYSTEM DESCRIPTION

- A 65K memory Westinghouse W2500 computer system will control the forge operation.

  - An H-P terminal with cassettes is the console.

  - Conrac monitors will be used for information display.

  - A line printer will be on-line.

  - Allen-Bradley and Modicon PLCs will be used to control and operate the machining centers.

INPUT

- A closed circuit TV system along with video recorders will be used all over the plant to monitor production line operations.

- The Westinghouse system will monitor about 1,200 I/O points.

    - Proximity switches and photoelectric relays will be used in addition to weight and temperature sensors.

- Little detailed hardware documentation is currently available.

    - The documentation is stored with the computer and is general, rather than detailed board layouts, etc.

- Westinghouse is supplying all software.

    - The operating system is the Westinghouse W2500 standard operating system.

    - Westinghouse is also supplying the necessary custom software written in FORTRAN.

- All software will be kept on cassettes.

    - Five copies of the software currently exist.

- The operating environment for the computer will be controlled and will meet the vendors' specifications.

    - There will be a generator to power the computer room separately from the rest of the plant.

- The dormant environment is planned to be controlled also, but the system will have to have the power turned off.

- Currently, the system is in a very dormant state. Since money was allocated for the system and other equipment at the beginning of construction, the system has been sitting in a warehouse for over a year.
    - The portion of the warehouse where the computer and other electronic equipment is stored has controlled temperature and humidity. However, only an unanchored plastic curtain separates the environmentally uncontrolled portion of the warehouse from the controlled portion.

3. OPERATING EXPERIENCE

- There was no operating experience as of the Fall of 1980, since the plant is still under construction.
- Mason-Chamberlin plans to maintain the system itself using the Westinghouse preventive maintenance plan as a base.
    - The plan is to have four or five technicians in the computer area while the plant is operational.
    - Diagnostics can be run on each IC board and for each I/O line on the board.

4. LAYAWAY AND REACTIVATION

- The Westinghouse system is currently stored in its original packing containers in a partially environmentally controlled warehouse. It is in effect "laid away."
- After the plant has "proven out" the plan is to lay the computer away with power off but to maintain the proper computer room environment.

- Even though there has been no reactivation experience with this system, the following two items seem important:
  - Westinghouse recommends that 45 to 60 days be planned to power-up the system especially the power supplies and capacitors - two critical components. If the contractor has only 90 days to bring the plant up to full production, waiting one-half to two-thirds of the allotted time just to get a computer started leaves the contractor very little time if something goes wrong.
  - The computer system is currently in a dormant state. When bringing the system up for the first time, many hardware problems will occur. An extensive failure monitoring system should be funded to try to glean as much information from the experience as possible. Attempts should be made to try to separate the failures due to storage and storage conditions from those due to first-time use.
- Electromechanical devices will be left in place, covered and protected.
- The magnetic cassettes and other magnetic storage media will need periodic recycling because the media will deteriorate with time.
- Software will be stored during dormancy in vaults in the computer area and main manufacturing area.

5. SPARE PARTS MANAGEMENT

- No formal program has been established since the plant is under construction.
  - A program as yet undefined will be organized when the electronics shop is set up.
- The contractor has a detailed listing from Westinghouse of every type of component in the system.

  - The contractor has alternative sources for spares because all components are standard off-the-shelf items.

  - Currently, there is no program to test spares as they are received.

6. PERSONNEL SKILLS PROGRAM

- Job specifications are currently being drawn up for all operating personnel.

  - There is a local NASA installation, and the contractor expects to be able to attract trained personnel.

- The contractor is planning to use standard classroom training and OJT for all new personnel.

7. FUTURE PLANS

- All programs are actually future plans for this plant.

- The contractor is planning to videotape the running of all equipment and use this in training programs and, more importantly, for reactivation purposes.

- It is planned to run the diagnostics bimonthly during plant operation, and at the same cycle clean the contacts on the IC boards of the PLCs.

8. MISCELLANEOUS

- The contractor is aware of the requirement to draw up a layaway plan for the entire plant and to pay particular attention to plans for the electronic equipment.

  - As of November 1980, little had been done along those lines, since the primary objective of all personnel is to get the plant built and operating.

- The ARRADCOM program is also expected to impact this issue of layaway.

G. RADFORD ARMY AMMUNITION PLANT

1. PLANT DESCRIPTION

- The Radford Army Ammunition Plant (RAAP) is operated by Hercules, Inc.
  - The plant was built about 1942 as an explosive powder and TNT manufacturing facility and has been operating continuously ever since.
- Two automated production lines are being built - one is in prove-out and the other is under design and construction.
  - The CASBL (Continuous Automated Single Base Line) system was designed in 1965, the installation was completed in 1975, and it is still in prove-out. It had not been started up as of November 1980.
  - The CAMBL (Continuous Automated Multi-Base Line) is currently under construction.
  - Both lines will produce propellants.
  - The single-base line (CASBL) is designed to produce 2,500,000 pounds of single base propellant per month in a continuous process. The multi-base line (CAMBL) combines several chemicals in the process of making propellant.
- The CASBL process line was designed by the Computer Sciences Corporation (CSC) and modified by Hercules, Inc.

2. ELECTRONIC PROCESS CONTROL SYSTEM DESCRIPTION

- The CASBL process control system uses a Foxboro PCP-88 computer as a base to control the successive operations of propellant mixing, extruding, cutting, drying and packing for shipment, as shown in Exhibit IV-12.
    - The computer system uses a pair of DEC PDP-8/Is as the CPUs, disk drives for mass storage, and a variety of peripherals, as shown in Exhibit IV-13.
    - The PCP-88 system is different than the VAAP and JAAP systems, primarily in the I/O complement. This system is card- and disk-oriented while the others are paper tape- and drum-oriented.
- In this system there are about 90 direct digital control loops. The system monitors 320 analog measurements and provides digital status and control for over 700 points.
    - Data from the sensors is sampled periodically, with the period determined by the sensor function.
        - Typically in this system, the sample interval is one second for a flow loop, five seconds for a pressure or level loop, and 30 seconds for a temperature loop.
- The supervisory computer, which is the backup computer, interrupts the DDC processor once per second to read the process variable from the core memory of the DDC. These variables are stored on the supervisory disk providing a very warm backup system in case the DDC has a failure.
    - Additional system backup is provided by an extensive analog system which, in turn, is backed up by a manual system.

EXHIBIT IV-12

PROCESS SAMPLING POINTS - CASBL MANUFACTURING AREA

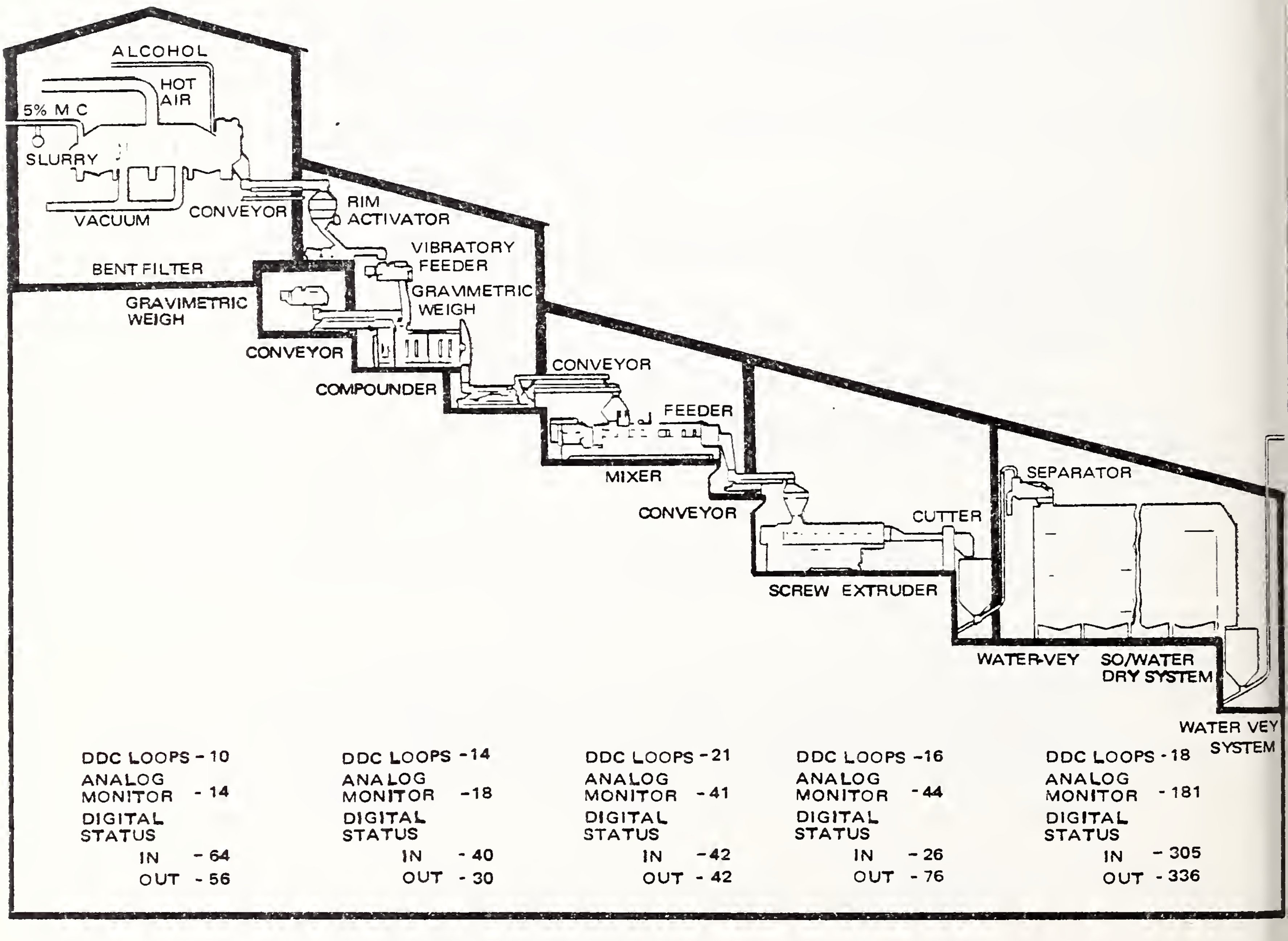
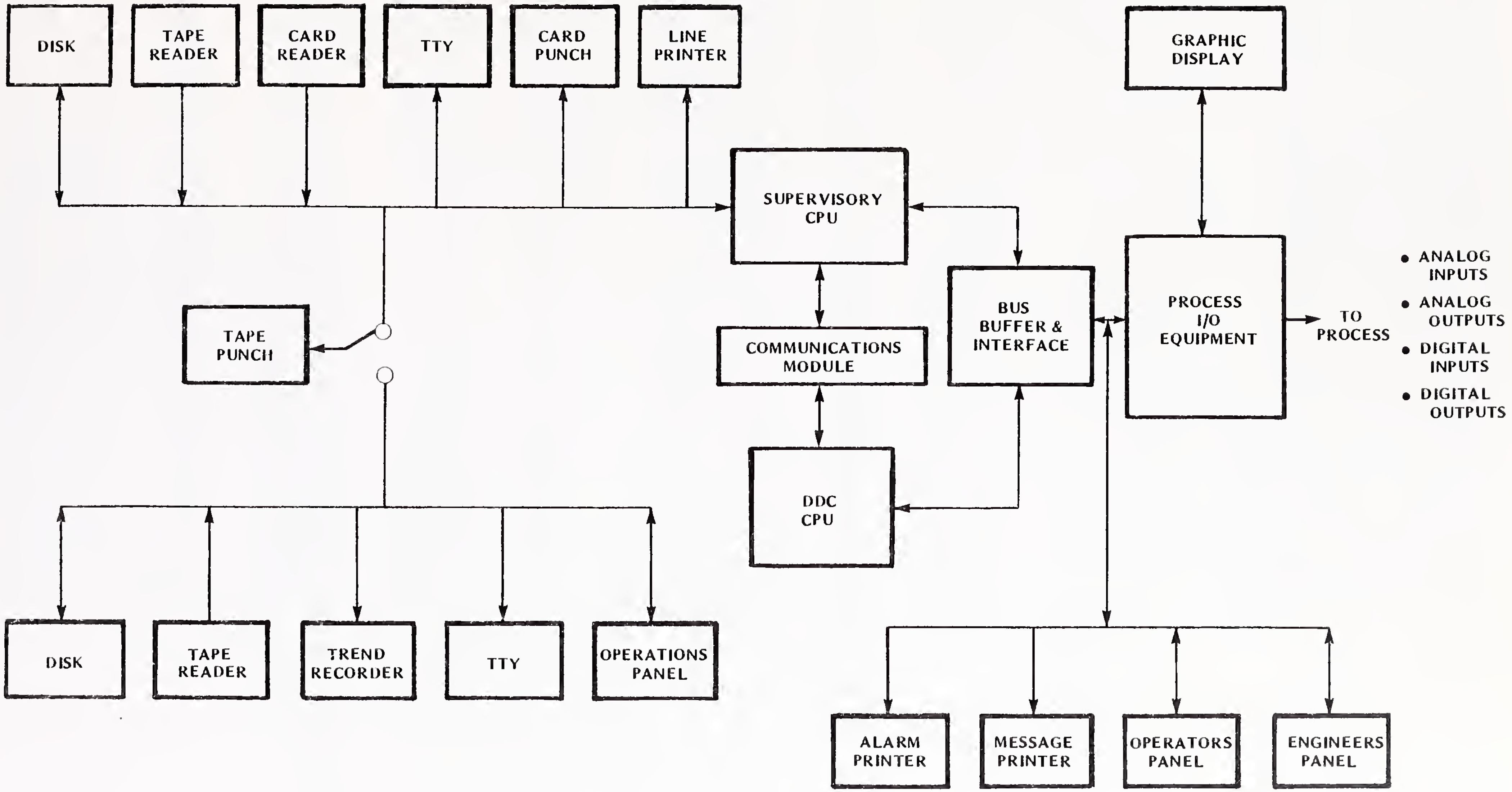


EXHIBIT IV-13

CASBL DUAL COMPUTER SYSTEM



  - Groups of failure detection routines are run every second as part of the continuous control software package. They are capable of detecting any out-of-limit conditions within the set point control, valve control, data entry, and analog conversion modules. A failed module will be disabled, the operator alerted, and if necessary shift to one of the backup systems.

- There is some feeling that the supervisory system is not a full backup. If there is an I/O problem or a failure in the data base, bus buffer, or interface, both systems go down.

  - The systems are not as completely separable as they should be in a true backup system design.

- In addition to the PCP-88 equipment, the automated lines include:

  - An Allen-Bradley PLC which is used to more precisely control the operational and safety aspects of the plant motor and solenoid valve control and to assume some of the more iterative plant "housekeeping" tasks.

  - A CCTV system which is used to monitor the entire production line.

  - A telephone system which provides voice communications along the process line.

- Standard software was supplied by Foxboro with the operating system originally furnished to Foxboro by DEC.

  - CSC wrote the applications programs and Hercules rewrote most of them.

  - The programs are written in Foxboro's language BATCH. Some reports are written in FORTRAN, and the data acquisition program is in BASIC.

- Programs are primarily stored on disk. Backup program storage is on verified paper tape.
    - Paper tapes are stored in the control room and eventually a copy may be kept in a vault. The paper tape is of standard quality.
- Hardware documentation is down to the board level. System documentation is extensive.
    - Software documentation consists primarily of assembly language listings and BATCH listings.
- The CAMBL system is similar to a bakery manufacturing process.
- Four Foxboro Fox I/A computers run four complex manufacturing towers.
    - Each computer complex has:
        - One line printer.
        - Two CRT displays.
        - One card reader.
        - One disk drive.
    - Each system has about 1,000 I/O lines to sensors and/or actuators, etc. The sensors measure pressure, temperature, and moisture content.
- Standard and custom software is being written by Foxboro.
    - All software at this point is kept on removable disks.
- Documentation is not extensive at this time (November 1980).

  - System documentation is the operations manual.
  - Logic prints to the board level are not defined.
  - Standard software has a fully annotated assembly listing.
  - Custom software documentation is a function of the language used, and source listings are the extent of the documentation.

- The computers for both lines are in a standard environmentally controlled room.

  - On the CASBL system, the interface and motor control rooms have strict temperature controls and heat vents.
  - On the CAMBL system, there is danger from acetone and alcohol, so all loops are "safe" loops with explosion-proof contacts.

3. OPERATING EXPERIENCE

- There has been no operating experience with either production line yet.

  - CASBL is in prove-out.
  - CAMBL is under construction.

- The potential propellant production from the lines is:

  - CASBL - 1.25 million pounds per month.
  - CAMBL - 2.4 million pounds per month.

- As of November 1980, one-half of the CASBL system had been checked out. The second half has yet to be calibrated or checked out.

- The CASBL system has a minimum record of system failures.
    - There is a log book of failures and a log book of major changes, but no one is really in charge of a "system" or overall "plan" for incorporating the changes into all the documentation.
    - No one exercises the responsibility of tracking failures in such a way that a change in preventive maintenance procedures might pick up the potential for failure before it occurs.
    - Computer memory has been the most troublesome area at this CASBL installation.
- In the CASBL system, the preventive maintenance plan calls for monthly maintenance by the plant maintenance department.
    - This plan was implemented, but it provides less maintenance than the vendor recommended.
    - Due to increased problems, the preventive maintenance plan has reverted back to the vendor's recommendation for specific equipment, notably the paper tape reader.
- No real thought has been given to maintenance plans or procedures on the CAMBL system.
    - There is some feeling that Foxboro may be needed to repair the system.

4. LAYAWAY AND REACTIVATION

- There has been no reactivation experience at either installation, nor have any systems been put in storage. Systems did not operate for some period during installation, but that is not considered layaway.

  - There are several ideas concerning how the CASBL system should be stored, but no definitive plan has been accepted and approved.

- It was felt that layaway and reactivation should be handled by the maintenance crew.

  - Most of this could be handled by the maintenance department if the procedures were written with this goal in mind.

  - Most I/O gear should be left in place, and those needing recalibration could probably be tested in place.

  - The line should be reactivated starting at the manual level, proceed to the analog system, and then to the digital system. This helps isolate problems to the most recently activated portion.

- The ARRADCOM program, as the VAAP plan, may be dovetailed into the CASBL and CAMBL plans.

5. SPARE PARTS MANAGEMENT

- For the CASBL system a listing of the major parts exists. The plan was to go into more detailed listings of both components and vendors, but the man in charge left and as of November 1980 no one had taken on that job.

- Spare parts for CASBL are stored in the manufacturer's packaging.

  - Spares are not dated or tested.

  - Board testers are not available, so parts have to be tested and faults diagnosed while the system is running.

  - The equipment is old, and there are generally few spare boards.

- The Allen-Bradley PLC has a complete set of spares.
- Vendors will not supply generic parts information, so it is very difficult to find alternative sources of parts.
    - Some feel that Hercules will have to design its own boards after Foxboro drops support for the PCP-88.
- The CAMBL system is still under warranty. It might be out of warranty before it can be installed.
    - Extended warranty is available, but the cost is extremely high.
- Hercules has a list of spare parts suggested by Foxboro and the Corps of Engineers.
- Hercules would like to get generic part descriptions from Foxboro.
    - Foxboro has relinquished some proprietary drawings.
    - Spares for the Fox I/A system are readily available since the system is still being marketed.
- Hercules' purchasing unit gets parts and instruments when necessary from whatever source can supply the right item.
    - Spares would be recycled if shelf life were critical, but no spares have been so designated yet.
    - There is no planned testing of spares for the CAMBL system.

6. PERSONNEL SKILLS PROGRAM

- The CASBL system will probably have a trained and dedicated technical crew when it goes into production.

  - There have been training sessions for technicians but, in general, there have been few ways for them to maintain their skills.

- The CAMBL technical people go through extensive training by Foxboro for 18 weeks, eight hours per day for five days per week.

- Beyond the above training, there is no plan for attracting and keeping skilled technicians to learn, run, and maintain the system.

  - During the prove-out and initial operations phases of the system there is sufficient challenge to attract skilled people. The problems may occur after the systems have been reliably producing for a few years and the initial people leave or are transferred.

- Hercules has been working with the local community college to set up electronic courses that will be pertinent to the needs at RAAP.

  - After these courses, it still takes at least six months in classes and OJT to train a good CASBL operator.

- There are plans to use various simulation training techniques in both CASBL and CAMBL training courses.

  - Personnel from within the plant have been trained and plans are to rotate them through all programs.

  - This produces highly salable people and the attrition rate may increase.

7. FUTURE PLANS

- The future of layaway and reactivation is cloudy at this point. The immediate future that must be addressed is to get CASBL productive and finish the construction of CAMBL so it can go to prove-out.

  - The lack of trained personnel is a long-term problem and limited steps are being taken.

8. MISCELLANEOUS

- In looking toward layaway and reactivation, one problem may be CASBL documentation which should be re-evaluated and brought up to date.

- The CAMBL system may experience some of the obsolescence problems that the PCP-88 system is having.

  - The Fox I/A system, while now being sold as part of the new Spectrum-compatible series, is an older system that was incorporated into the Spectrum line.

  - It is not compatible within the spectrum line as are some of the newer processors.

  - The interfacing of the I/O lines and peripheral equipment is, however, much more compatible within the Spectrum family than is possible within the PCP-88 line, which is a dead end.

  - As of this writing it is understood that the Fox I/A system will be replaced with a "new" system.

H. VOLUNTEER ARMY AMMUNITION PLANT

1. PLANT DESCRIPTION

- The Volunteer Army Ammunition Plant (VAAP) is an 8,000-acre TNT manufacturing facility operated by ICI-Americas for the U.S. Army.

- The plant was initially built in the 1941-1942 period by the Corps of Engineers.
  - The EPC system was designed in 1971 and accepted in 1974.
- The plant has 10 TNT production lines.
  - Four are batch production lines.
  - Six are CIL continuous process lines with four of these lines under direct digital control.
- The entire plant is laid away and is in standby status.
  - Only one DDC line was ever operated, and it produced TNT for about 15 months before being shut down.

2. ELECTRONIC PROCESS CONTROL SYSTEM DESCRIPTION

- The EPC system at Volunteer is a PCP-88 system from The Foxboro Company and was designed jointly by Foxboro and ICI-Americas (formerly Atlas Chemical Industries).
  - The system is a twin of the one at JAAP; a simplified computer diagram was shown in Exhibit IV-2.
- A Foxboro Spec-200 system is used for backup alarm monitoring and emergency line shutdown.
- The system includes both analog and manual backup equipment.
- The sensors and instruments are electronic except for the valve actuators which are pneumatic.
- I/O equipment, other than the control lines, is minimal.

  - Magnetic drums are used for mass storage.

  - Paper tape readers and a paper tape punch, along with typewriter-type printers, make up the rest of the peripheral equipment complement.

- The software is DEC and Foxboro standard programs plus custom work by Foxboro, expanding the capability of the system to handle 10 lines.

  - The scan rate was changed from one second to two seconds permitting more lines to be scanned in the interim.

- Machine language and FORTRAN II were used for the programs.

  - The programs are stored on the drum and on paper tape.

- Hardware documentation exists in great detail.

  - It was found in training classes, however, that the drawings did not match the actual physical installation.

- Software documentation is felt to be more accurate than the hardware and just as complete.

- The operating environment is computer "standard" - temperature kept in the low seventies and humidity in the low forties.

  - The system seems to be temperature sensitive and performs unpredictably if the temperature goes over 80°F.

  - The air is double filtered to ensure protection against acid fumes getting into the computer room as happened on one occasion.

3. OPERATING EXPERIENCE

- During the 15 months the line was operating, production averaged 50 tons per day.
  - The maximum capability of the line is 70 tons per day which was achieved several times.
- The entire system averaged 80% uptime while the computer averaged 98% uptime.
  - There were some initial problems that couldn't be specifically isolated, but adding wiring shields eliminated the problems and the system ran smoothly.
- A daily log is kept which tracks all interaction with the system including problems and fixes.
- An overall preventive maintenance program was in effect while the system was operating.
  - There appeared to be no need to modify the program since the system ran smoothly.
  - Preventive maintenance scheduling is now computerized.
- Some changes were made to improve system reliability during the production running period.
  - Some sensors failed and had to be redesigned. Specifically, the differential pressure cells wore out the orifices and magnetic flow meters were substituted for the cells.

  - A mixed acid analyzer and gas chromatograph were added on-line, but the line was shut down before they could be tested.

4. LAYAWAY AND REACTIVATION

- The DDC-TNT line was shut down in March 1977, and the computer was turned off in July 1979 based upon guidelines of the ARRADCOM layaway plan.

- The computer environment was kept the same as it was when in operation.

  - The relay racks and the Spec 200 are also kept in a controlled environment.

  - Some sensors and other remote I/O devices were removed and placed in a controlled environment.

  - Some electronic devices were kept in place and desiccants were kept in the cabinets.

  - Most valves were left in place. Those in the outside settling areas were put in uncontrolled storage.

  - The helium environment of the magnetic drum was maintained.

- All documentation is kept in the computer room and in a vault.

- The system was reactivated under the ARRADCOM layaway plan after nine months in March-April 1980.

  - Several small problems occurred that in combination turned out to be major problems.

  - The problems were mainly with some IC chips especially with the pins and sockets.

  - Some of these problems might have been generated by the nitric fumes accident a few years earlier.

  - Also, in the nine-month period people became unfamiliar with the details of the system, and this prolonged the reactivation time.

- The PCP-88 system was reactivated again in September 1980 for a training class sponsored by the ARRCOM personnel resources program. This reactivation was much less traumatic than the first.

5. SPARE PARTS MANAGEMENT

- There is no dedicated program aimed at compiling and maintaining a list of all vendors whose components are used in the system.

  - An incomplete ad hoc list exists.

- A formal spare parts program existed during production but has lapsed during dormancy.

  - Vendor support in this area is good, but Foxboro's inventory has become depleted and now other sources of spares must be located.

- There is no current formal program to identify alternative sources of components.

  - There is no program to test "compatible" components or to test spares to see if they are operational.

- Foxboro suggested that ICI or the Army buy old PCP-88 systems as a source of spares as they are replaced at other installations.

6. PERSONNEL SKILLS PROGRAM

- TNT-making skills are rapidly vanishing in the U.S. because no TNT is currently being made, nor do there seem to be plans to make any soon.

- DDC classes are held regularly for new people brought on board through various programs.

    - Volunteer does its own training using audio/visual materials made by ICI-Americas, and also some supplied by Foxboro.

- Holding on to people is a major problem.

    - No steady sources of new personnel are available.

- The Army has a personnel resources program which keeps track of military personnel by skill.

    - ICI-Americas tracks its own people as long as they remain with the company.

- Foxboro is the only training vendor for this system.

7. FUTURE PLANS

- Currently, the three ammunition plants that have PCP-88 systems are jointly defining a program outlining their alternatives and making recommendations in light of the withdrawal of support for the system by Foxboro.

- An Army ammunition plant personnel resources program for the civilian employees with attempts to track them when they leave has been talked about, but sufficient interest hasn't yet been aroused to fund such a program.

- The making of televison tapes of the training program would preserve the courses in the best possible way if professionally done and if the PCP-88s remain.

8. MISCELLANEOUS

- Mention was made of the possibility of using the local Army reserve unit as a trained basic cadre for the system.

  - They could, after training, bring the system up each year as part of their active duty.

V MAINTENANCE METHODOLOGIES

V MAINTENANCE METHODOLOGIES

A. INTRODUCTION

- This chapter pulls together the information gathered from the vendor and user interviews.

    - There is no "right" approach presented here, but merely an analysis and summation of the views of many respondents - sometimes several in each of the companies.

- All the respondents were cooperative; some users were confused.

    - They spend their time trying to keep the system running 99.9% of the time, yet the interview topic concerned shutting the system down. The thought was very alien to their thinking.

    - Most vendors also hadn't given the layaway problem any thought, but when the requirement was laid out before them they became intrigued. This, of course, doesn't make their responses any more or less valid.

- Each type of respondent took a different tack toward maintenance. Some responses were more appropriate than others, but none could present hard data to support their views which usually called for a "play-it-safe" policy.

- Only one company, a leasing company, could say that systems can be stored under normal warehouse conditions with minimal ill effects.

B. VENDOR ANALYSIS

1. SYSTEM VENDORS

- The types of vendors interviewed are shown in Exhibit V-1. They ranged from manufacturers specializing in programmable controllers and industrial controls specifically, to manufacturers of total electronic process control systems.

a. Status of Current Systems

- Current systems have provided excellent performance relative to application, availability and failure rate. Some have been operational until a decision has been made to upgrade the system.

- Design considerations varied with the vendor's marketplace and application. The common goal of all vendors, however, was to improve hardware and software.

  - Redundancy was built into areas of critical circuit functions in order to maintain integrity of the process.

  - Certain critical functions were decoupled, or unbundled using modular design to minimize risks of a common failure element.

  - The modular design concept of the overall architecture was improved. This concept places a circuit, or multiple circuits and their functions, on individual plug-in type subassemblies. These subassemblies can then readily be removed and replaced with a known working replacement.

EXHIBIT V-1

TYPES OF VENDORS INTERVIEWED

VENDOR	INDUSTRY
1	TRAFFIC COUNTERS, INDUSTRIAL SCALES, TRUCK/RAIL WEIGHING STATIONS
2	INSTRUMENTS, SENSORS, ACTUATORS
3	PROGRAMMABLE LOGIC CONTROLLERS
4	MINICOMPUTERS AND MICROPROCESSORS
5	EPC SYSTEMS
6	EPC SYSTEMS
7	EPC SYSTEMS
8	MICROPROCESSOR MEASUREMENT AND CONTROL SYSTEMS
9	EPC SYSTEM
10	EPC SYSTEMS
11	PROGRAMMABLE LOGIC CONTROLLERS
12	EPC SYSTEMS
13	EPC SYSTEMS
14	PROGRAMMABLE LOGIC CONTROLLERS
15	PROGRAMMABLE LOGIC CONTROLLERS

  - Current systems also have self-diagnostic capability which simplifies troubleshooting to the defective module.

  - Software was simplified for the nontechnical operator. This software is menu driven, and constantly prompts the operator to answer questions before advancing to the next step.

  - Combining such functions as analog and sequential latch control eliminated the need for multiple microprocessors.

  - Emphasis on ladder logic has been to simplify maintenance for the customer facility electrician.

- The decreasing cost of hardware offers much more product for the money compared to ten years ago. As a result, tradeoffs are less likely to be considered.

  - The decreasing cost of hardware enables a vendor to be more selective with discrete components - improving equipment reliability.

  - The modular design of equipment architecture does not force a customer to start with a system any larger than his immediate need, as might have been done ten years ago.

    - A customer with a small need can begin with a small dollar investment and expand as the need requires.

- Vendors were hesitant to discuss MTBF (Mean Time Between Failures), since it has a different meaning to each vendor.

  - MTBF formulae vary with each vendor.

  - Design engineering is normally required to estimate MTBF for each product designed. This is intended to aid projections for the critical support areas such as logistics and staffing. Engineering's estimates of MTBF are frequently conservative.

    - One vendor's empirical data reflected an MTBF that was 6 to 10 times greater than expected by mil-spec 217C.

  - Quality control traditionally records all historical data provided by customer service. This information is then compared with the established MTBF and MTSF formulae (Mean Time to System Failure).

  - This equation is usually a function of failure rate, repair rate, test interval, operate time, and system redundancy.

  - Selected MTBF and MTSF data, particularly low figures, are then given to engineering for possible design changes that will improve the MTBF and MTSF.

- Of the 15 vendors interviewed, only one was mil-spec oriented.

  - INPUT discovered that most vendors believed in a willingness on the part of the user to trade off higher equipment costs for improved reliability.

  - Some vendors, however, could not justify the increased cost associated with mil-spec on the theory that a device is only as good as its weakest link, and not all components used meet mil-specs.

    - In addition, vendors do not use mil-spec components because they could not then meet the price competition in the marketplace.

  - Mil-spec 217B's guidelines are used by some vendors for MTBF calculations.

- Packaging techniques for components varied with the vendor's targeted marketplace, application and environment.

  - One vendor applies a special varnish to PC boards to minimize the effects of moisture. This procedure, however, makes troubleshooting and repair more difficult, since the varnish is hard to penetrate with test equipment probes, or the required unsoldering and soldering of discrete components.

  - Another vendor offers an optional cabinet containing a water-heater exchanger for use in locations with extreme environmental problems.

  - The highly competitive components market encourages vendors to use standard components as a means of maximizing component resources.

- Equipment performance has shown steady improvement due to the improved development of such components as ICs.

  - With IC functional component densities approaching 50,000 and 100,000 transistors, concern is being voiced over the quality and performance of the chips.

- Vendors had little comment regarding system or subassembly weaknesses. Most felt there were no weaknesses of significance.

  - The reliability of IC sockets is always of some concern when ICs are plugged in, as opposed to being soldered in place.

  - When ICs are plugged into a socket, there is concern for two basic variables:

    - The human element responsible for inserting the IC.

    - Proper handling during packing, shipment and unpacking.

- Another area of concern is the proper design of and manufacturing process for isolating sensitive circuits from 60-cycle power sources.

  - Since most equipment operates at very low voltages, 60-cycle noise can play havoc.

- Proper electrical grounding throughout a system is equally important in order to eliminate or minimize the effects of static electricity. If not properly grounded, static electricity can prove hazardous to operators and is also capable of repeatedly destroying software programs held within memory.

b. Support Plan

- Dramatic technological advances compel the vendor to constantly review its maintenance strategy in order to ensure that it complements the latest product. This is particularly true of vendor service organizations that are profit centers.

- Support problems are greater for customers who find it necessary to contract overall system design with multiple vendors, because of the difficulty of coordinating the combined efforts of the vendors. In such a situation, individual vendors are insensitive to the customer need for network coordination.

  - Given these circumstances, it is not uncommon for a customer to identify one vendor as the primary contractor assuming the responsibility for overall coordination and project management.

- In all cases, the customer is responsible for site preparation which includes satisfying environmental specifications, power requirements, cable laying and spares for the hardware.

- Vendors are committed to some form of support, primarily parts during the warranty period.

- Vendors of the more sophisticated total electronic process control systems will assume installation and startup responsibility.

- Vendors of the less sophisticated systems, consisting of programmable logic controllers only, will provide telephone support during installation and startup. On-site support is provided on an as required basis.

  - The less sophisticated systems such as standalone programmable logic controllers usually enable the customer to purchase parts locally from vendor support locations or vendor-appointed distributors.

  - These programmable controllers are usually purchased from local distributors, who provide the first line of support including maintenance and spare parts.

- Generally, only vendors of total EPC systems offer maintenance contracts on hardware and software. There are two basic reasons for this:

  - The vendor is in the service business and retains a staff of qualified support personnel trained on the product line.

  - The customer is not in the service business due to the magnitude and sophistication of such systems, and generally cannot justify the costs related to establishing such a service unit.

- All vendors make hardware and software maintenance training available. Initial training usually occurs before delivery, during factory checkout and acceptance, or at times during the warranty period.

- The vendor, who obligates the customer to installation, startup and on-going maintenance, will provide timely training as part of the overall purchase.

- Vendors of the more sophisticated total systems will provide continuing hardware and software training at an additional cost.

- The vendor assumes that customer personnel sent for training have a basic understanding of electricity and/or electronics for hardware maintenance. It is also assumed that individuals sent for software training have a basic understanding of software.

- No vendor is prepared to train neophytes under any circumstances.

- Licensed distributors of vendors are also prepared to provide limited training for hardware and software maintenance.

- Preventive Maintenance (PM) is usually identified with electromechanical devices such as printers, card reader/sorter, and tape drives. Totally electronic devices such as video displays and microprocessors do not qualify for PM.

  - Electromechanical devices have more moving parts and, therefore, more breakdowns; electronic devices, with less moving parts, have less breakdowns so that it becomes uneconomical to have a preventive maintenance program for them.

- Any device, however, left in a totally dormant and inactive state for extended periods should be examined for corrosion, dirt and free movement of normally moving parts before it is activated.

  - Under a maintenance contract, PM will be performed on a regularly scheduled basis dictated by the environment.

  - Parts within an electromechanical device that tend to be in constant motion, or are constantly being abused by a moving part such as head pads, belts, gears, reed switches, or microswitches, are normally examined and replaced routinely during each PM. Most of these parts are considered expendable.

  - The device is normally thoroughly cleaned, vacuumed and lubricated where necessary.

  - Filters are either replaced or cleaned depending on the type.

  - Magnetic heads in tape drives and disk units are also cleaned. Occasionally, heads can become pitted as the result of abrasive material collecting directly on the head, or from scratched or damaged media (tape or disk). Under such circumstances, these heads require burnishing and calibrating. It is recommended that these units be returned to the vendor for repair and alignment.

- Attention to the aesthetics of a device is also included in a good PM routine. Included are such things as:

  - Cleaning CRT screens.

  - Video adjustments.

  - Cleaning keyboards.

  - Cleaning cabinets.

  - Replacing CRTs with phosphor burns at a nominal cost.

- A well defined and disciplined PM program will prolong equipment life and contribute significantly to the system availability.

- On-site maintenance can be performed by either the vendor or user. This is usually dictated by the system configuration and the user's ability to perform maintenance.

  - Sophisticated total electronic processing control systems are usually maintained by the vendor's field engineering staff.

- This can be handled in one of three ways.

  - A maintenance contract committing a resident field engineer to be dedicated to the user.

  - A maintenance contract committing a field engineer to arrive on-site within a specified time, usually four hours from receipt of the service call.

  - A Time and Materials (T&M) contract that simply places a customer in a queue for service. The vendor is not obligated to respond in a specified timeframe. Customers with maintenance contracts have priority.

- Facility electricians working for the user can be adequately trained to maintain less complicated systems consisting of programmable logic controllers (PLCs) and related sensors.

  - Vendors of simpler systems, consisting of nothing more than PLCs, do not usually offer maintenance contracts. It is the consensus that customers can be trained adequately to perform their own maintenance.

  - Since modular design is commonplace with today's hardware architecture, the maintenance philosophy is to isolate the failed module/component, remove it, and replace it with a known working module/component.

- Vendors, in general, maintain a respectable degree of sensitivity to customer service needs under any circumstances.

- Off-site maintenance generally refers to repairs performed at the vendor's repair depot. Vendors may maintain one or more strategically located depots. Their location is usually dictated by two important factors - equipment concentration and transportation.

    - In the case of multiple depot locations supporting a large product line variety, it is conceivable that each one will have different levels of maintenance responsibility. That is, a depot may specialize in a specific product requiring special handling.

    - This specialization provides quality repair due to the repetitive nature of its support function, excellent quality control, and faster turnaround time for local customers, as well as customers and FEs elsewhere.

    - Under any circumstances, the depot located at vendor headquarters is capable of total repair support for the customer.

    - Remote diagnostic capability for hardware/software problem determination in total EPC systems offers another alternative under certain conditions.

- Labor costs rising at an annual rate of 12% to 15% force field engineering organizations to demonstrate their ability to function profitably. The commitment to implement cost controls, increase the field engineer's productivity, and maintain the image of being a viable organization is a challenge of large dimension.

    - The field engineer's productivity is increased through effective utilization. This is accomplished through proper training in all areas of responsibility including hardware troubleshooting techniques and communication skills dealing with the customers and support personnel.

  - The emphasis on communications will also reduce the "repeat call" and "no fault found" syndrome.

- Training programs for both the vendor and customer will constantly be reviewed to complement new products.

- A well defined escalation process for both the vendor and customer will also expedite effective and timely support.

- Improved equipment design and reliability will improve system availability while decreasing the MTBF.

- Backup support specialists are available to vendor field personnel, as well as the customer.

- Consideration is also given to the removal of chronic devices detrimental to customer system availability and field engineering productivity. These devices are usually targets for a thorough overhaul or scrap.

- Emphasis on modular design of hardware and software impacts favorably on Mean Time To Repair (MTTR). That is, the partitioning of hardware and some software components permits the rapid replacement of a failed component, once it has been identified.

- Absolute control of inventory requirements is another major cost consideration. Economies of scale are achieved by maintaining an inventory of parts with the lowest MTBF; in other words, the most common and frequently failing components.

- Interchangeable parts can be readily identified via a cross-reference chart scheme. This expedites repair whenever a direct replacement is unavailable.

- Documentation is normally included in the sale of a device or system. The level of documentation is consistent with the customer need and supports both the hardware and software.

  - Manuals written specifically for customer use adequately describe the theory of operation for each functional area of the device or system. These manuals include block diagrams and logic diagrams.

  - Maintenance manuals are not usually provided for electronic equipment, but are provided for electromechanical devices. These manuals provide considerable detail of all mechanical and electronic circuits. Electronic equipment circuitry is much larger in scope due to packaging and would require extensive maintenance documentation.

  - Software reference manuals describing the language used and assembly-level programming assume that the customer is familiar with these topics.

- Spare parts management is of little concern for customers having a maintenance contract. Such contracts normally obligate the vendor to total logistics responsibility. Customers without a maintenance contract must consider purchasing a recommended list of spares.

  - The level of supporting inventory is determined by usage. This information is gathered from historical data depicting all details of equipment performance.

  - Individual customer apprehensions will also impact the type and level of required inventory.

  - Recommended spares usually represent 10% of the equipment purchase price.

  - Obsolescence in the commercial market is not a major concern since most vendors will support the product for at least 5 to 10 years. Should a customer retain the equipment beyond this period, parts can be custom made from the original artwork, albeit at great expense.

  - Parts are shipped in appropriate protective containers. Vendors suggested that such containers should be retained for reuse until they are no longer usable. However, if the containers are made of Kraft paper or the parts are stored in corrugated cardboard boxes for long periods of time, the sulphur may seriously degrade the parts.

- The warranty period commits the vendor to total customer support. Beyond the warranty period, the customer will negotiate a maintenance contract or assume a maintenance posture.

  - Before system acceptance, the vendor is obligated to satisfy final checkout and acceptance. This includes logistics support.

  - Customers purchasing less complex systems using nothing more than programmable controllers frequently perform installation as well as maintenance. The vendor and/or distributor continues to be liable for startup problems within the equipment.

- Post-acceptance support is available from the vendor depending on the scope of the system configuration and the customer need. Vendor personnel skill levels will range from a technical school graduate to a BSEE and, in some cases, a PhD.

  - Active support of this type is usually available from the vendor for periods of five years from purchase and installation on an "as required basis."

c. Dormancy

- The operation of processing plants, which are subject to shutdown or layaway, can be divided into three phases: dormant phase, startup phase, and operational phase.

    - In the dormant phase, the system has been deactivated and is in layaway. Periodic tests of system operational readiness may be required to identify dormancy failures and initiate module repair or replacement.

    - The startup phase occurs during mobilization and may involve a sequenced initialization of individual components. Detailed diagnostic tests may be required at all levels to verify operational readiness of each element within the system before the next step in the sequence can be taken.

    - The operational phase enables the continuous manufacturing process.

- Forty-seven percent of the vendors interviewed had no experience with dormancy. The remaining 53% had limited experience with dormancy but had definite ideas and recommendations.

    - Forty-four percent favored keeping the system in a ready mode. That is, the system should be on and operating in some mode. The mode of operation would depend on individual circumstances such as:

        - If there is a need for further software development or revision, the operating mode could support this effort, enabling the system to be on during the dormant period.

        - If there is no need for further software development, the operating mode could be a repetitive self-test of all critical functions.

- Selected, or all, sensors could be shut down, while the central elements such as the processor and related programmable controllers and other peripheral devices continue to be exercised in some predetermined mode.

- All vendors expressed little or no concern for equipment in a dormant state provided there was strict adherence to environmental control.

  - Parameters of environmental control included a temperature range of -40°F to +40°C and noncondensing humidity of 0% to 95%.

- If the dormant state of a munitions plant does not lend itself to keeping a system in a ready (on) state, periodic tests of system elements may be useful in minimizing plant startup time by identifying failures before mobilization.

  - A technique known as Test Interval Analysis (TIA), detailed in Exhibits V-2 and V-3, may be useful in determining the maximum time interval between such tests for a given level of system reliability.

  - This approach allows the designer to perform an economic tradeoff between the frequency of tests and the resultant reliability of the system.

- The memory component of most electronic process control systems utilizes a backup battery power source. This design feature is intended to prevent destruction of the operating software and any other pertinent data being held in memory during power failures.

  - The life of these alternative power sources varies from 72 hours to three months.

  - Vendors recommend that during planned dormant periods, the battery packs be removed until the system is reactivated.

EXHIBIT V-2

TEST INTERVAL ANALYSIS

- Prepare a list of all system components/modules.
- Estimate the failure rate of each component/module for both the operational and dormant modes.
- Perform a Failure Modes and Effects Analysis (FMEA) as itemized in Exhibit V-3.
- Construct an equation which mathematically represents the reliability of the system. The equation is a function of failure rate, repair rate, test interval and operate time.
- Solve the equation, at the specified reliability level, for the test interval.

EXHIBIT V-3

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

- Used to identify credible modes of failure and to evaluate their consequence.
- Prepare a list of all system components/modules.
- For each component/module, list every possible credible failure mode.
- For each failure mode, list the following:
  - Possible failure mechanism
  - Symptoms and local effects (including dependent failures)
  - Method of detection.
  - Inherent compensating provision.
  - Effect on system.
  - Remarks and other effects.

- If the dormant period is expected to last for extended periods of six months or more, selected components such as the microprocessor, disk, and other units sensitive to environmental conditions can be packed away.
    - Original containers should be retained for this reason. The components should be packed as they were originally and again stored in a controlled environment. The containers do not permit any deviation from the controlled environment.
    - If the original containers are not available, heavy duty plastic bags will suffice.
    - An appropriate covering should be used as well for the associated remote components such as programmable controllers and sensors that cannot be readily packed away.
    - The economics and practicality of packing anything away should receive careful consideration, especially since it entails disconnecting equipment that will eventually require reinstallation.
    - Spares inventory should receive similar care.
- When components are unpacked after a lengthy storage period, they should be physically examined for corrosion and condensation.
    - This is particularly true of all types of male-female connectors on PC board planes and magnetic heads on disk and tape components.
    - Electromechanical devices such as printers should also receive a thorough going over for free movement of heads and shafts. These should receive PM before being placed into operation.

  - Once the physical examination of components is satisfactorily completed, they should be placed into position and connected in accordance with the original configuration.

- The greatest caution must now be exercised by strict adherence to the vendor-specified turn-on sequence. Otherwise, hardware failures may occur.

- Failure tracking varies with the maintenance responsibility. It is a routine responsibility for the vendor performing the maintenance. Customers performing the maintenance tend to be lax.

  - Field engineers are required to complete a service report on every action taken. This document, in many cases, is a 100% reporting tool. It becomes a key ingredient to a management information system, tracking not only the FE productivity but the performance level on every system component. This includes, of course, failed parts.

  - This failure data is utilized by the quality control department to alert production and engineering to potential changes, if required. Quality control can usually provide complete historical data on every component shipped to a customer.

  - This type of feedback is key to eliminating repetitive problems.

- Most vendors felt comfortable with a reactivation and diagnostic frequency of one-month intervals. One vendor indicated the frequency would be dictated by the type of manufacturing process. The more sophisticated the manufacturing process, the more frequent the reactivation.

  - While all vendors expressed little or no concern for dormancy, they favored keeping the system on and in a ready mode. There was also general agreement that shutting a system down for a period would not create any catastrophic failures at reactivation, providing there was strict adherence to environmental control.

- Maintaining a system in an "on" or "ready" state offers four advantages:

  - System maturity without abnormal degradation.

  - Minimum corrosion and condensation.

  - Near immediate operational status.

  - Increased confidence level.

- Maintaining a system in a ready state necessitates a staff of at least one trained person to be available for monitoring system performance.

d. Maintenance Philosophy

- Vendor maintenance philosophy is simply to effect a repair in as short a time as possible. This benefits the vendor as well as the customer. Since a service organization constantly works in a negative environment, it behooves the vendor to maintain a low profile. Thus, the thought, "fix it and get out."

  - This philosophy is prevalent for vendors who have assumed maintenance responsibility. There is little or no control by the vendor where a customer has assumed the maintenance posture.

  - Current modular design and increased reliability in hardware architecture have contributed to a marked improvement in MTTR.

- Maintenance contracts generally commit to service "within four hours" of receipt of the service request or "next half-day." That is, should the service call be placed in the morning, service can be expected in the afternoon. Should the call be placed in the afternoon, service will arrive the following morning.

  - Vendors are discretionary about committing a resident field engineer, as they focus on productivity and costs. Customers that have such a requirement can have it included in the maintenance contract for the appropriate costs.

  - Customers in remote locations will experience higher maintenance costs and longer response times.

- Built-in self-diagnostics permit the field engineer to expedite repair. Simultaneously, they simplify trouble-shooting for the trained customers. This provides considerable improvement in equipment availability.

  - Currently, the level of customer participation in maintenance is usually poorly defined. It should be restricted to isolating the defective module and replacing it. Customers should not troubleshoot to the component level.

- Preventive maintenance is performed routinely on a predetermined schedule. This is good practice for equipment in use or in a dormant state. It includes running diagnostic routines and replacing worn parts, cleaning, and lubrication.

- Hardware and software maintenance are generally performed by separate personnel. While some cross-training does take place, it is not yet prevalent.

- Every customer service organization has an escalation procedure. The intent is to expedite the marshalling of all resources required to solve a problem.

- Vendors of the more sophisticated total electronic processing control systems encourage customers to opt for a maintenance contract. The primary reason is that the vendor is prepared with a trained staff, whereas the customer usually cannot justify the related overhead and inventory expense.

  - Maintenance is usually contracted for one year and is renewable.

  - Customers can also opt for a T&M contract, where only the costs related to each service call are paid.

- Vendors performing maintenance as their principal business tend to display a greater sense of urgency and sensitivity than do customers performing their own maintenance.

    - This is because it is not the customer's principal business. Therefore, it is an inherent characteristic of customers performing their own maintenance to be complacent, except in the case of major failures.

- Maintenance personnel skills requirements vary with the vendor and system configuration. Manufacturers of electronic processing control systems and sophisticated programmable controllers feel that advanced skills are required.

  - Forty-seven percent of the vendors interviewed required graduates of technical schools trained by the vendor for maintenance of the hardware and for reactivation.

  - Thirty-three percent encouraged training of skilled customer facilities electricians for maintenance of the hardware and for reactivation.

  - Thirteen percent of the responding vendors required their own personnel to have a BSEE degree supported by the vendors' own technicians for maintenance of the hardware and for reactivation.

  - They indicated four sources for such personnel:

    - Undergraduate technical schools.

    - Technical schools.

    - Competitors.

    - Customers.

- All vendors offer training programs to customers. Hardware training programs are structured to train customer-skilled facilities electricians for simple and logical trouble isolation. There is little or no theory of operation. Software training assumes a basic working knowledge of software.

  - Twenty percent of the vendors mixed on-the-job training with formal training. The remaining vendors provided formal training only.

- All vendors had a method, crude or otherwise, for tracking the movement of their maintenance personnel. The tracking method varied with the type of dispatching scheme.

  - Regardless of the tracking method used, the primary responsibility for notification of a field engineer's whereabouts belonged to the field engineer.

  - Computerized central dispatching networks tracked an individual's location in real-time. This method readily enables a manager to divert the best qualified field engineer nearest to a site with a maintenance requirement.

  - Satellite maintenance offices without the luxury of a sophisticated central dispatch function must depend on the dispatcher's knowledge of their whereabouts. The dispatcher, in turn, must depend upon the field engineer to report his location constantly.

2. MAINTENANCE SERVICE VENDORS

a. General Climate

- System manufacturing companies have their own in-house field engineering (maintenance) organizations. These FE organizations are increasingly becoming profit centers, as shown in Exhibit V-4, and as they do, the prime difference between a captive FE organization and a pure maintenance service organization will be the brand of equipment maintained.

  - The captive organization maintains only one vendor's equipment, while the maintenance service organization maintains several brands of equipment.

- In general, both kinds of organizations have similar personnel, equipment, and customer problems.

- System maintenance is a dynamic, rapidly growing area that will blossom in the 1980s as a major growth industry.

  - Organizational structures are changing to meet new needs. Seventy percent of the vendors created major changes during 1980.

  - In addition to structural changes, the number of field engineering locations increased by 15%.

- Recruiting and adequate diagnostic equipment were highest on the list of rated concerns by vendor FE organizations, as shown in Exhibit V-5.

  - These two problems have or will be experienced by the operating contractors also. Since the contractors compete in the open market for personnel, the lack of skilled personnel will make recruiting difficult. Test equipment for maintaining equipment or for testing spares is minimal.

- All vendor field engineering organizations (in a previous INPUT study) averaged equipment availability from 95% to 96.4%, as shown in Exhibit V-6.

EXHIBIT V-4

PROFIT CENTER OR COST CENTER
ORGANIZATION OF RESPONDING VENDORS

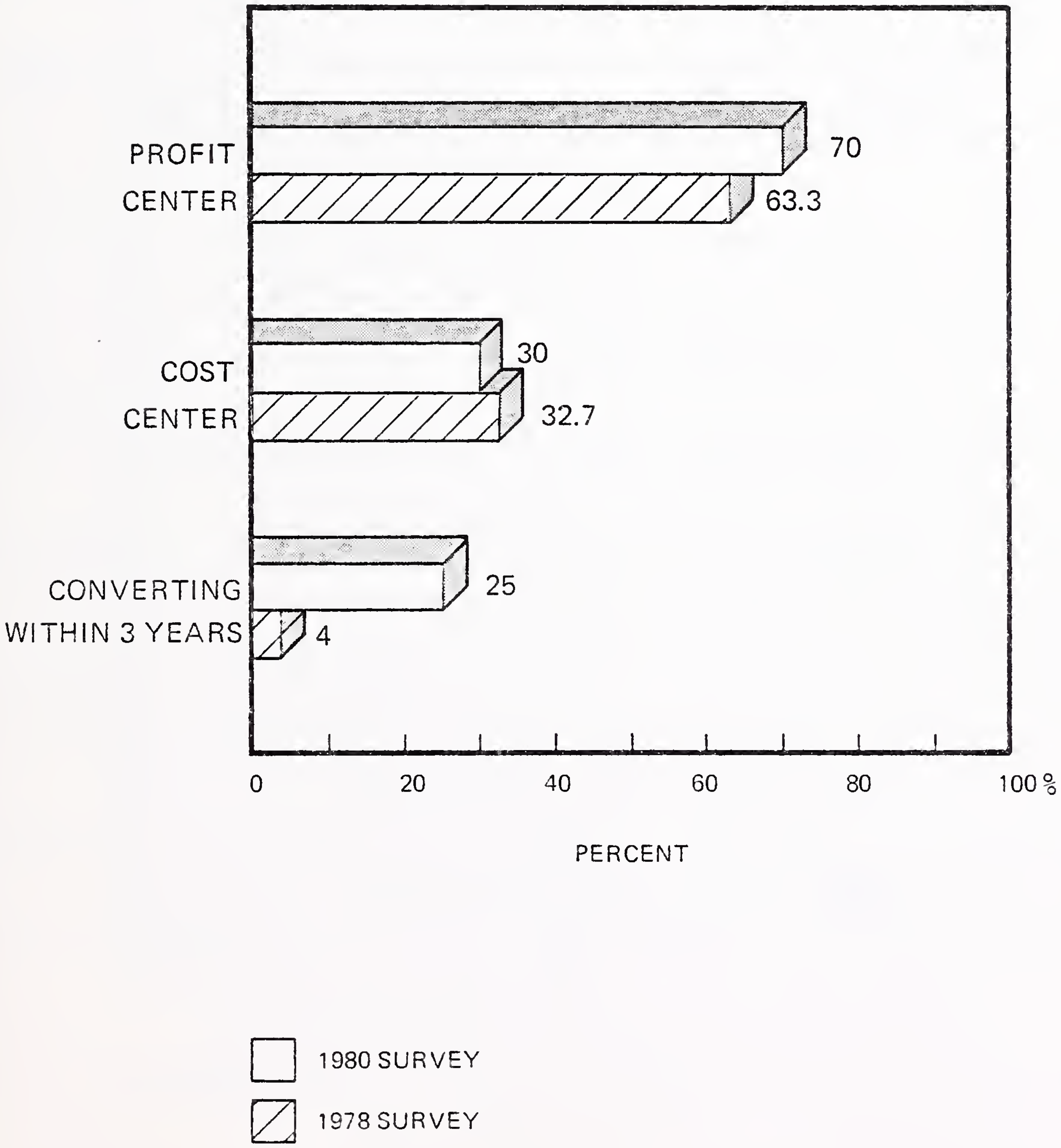
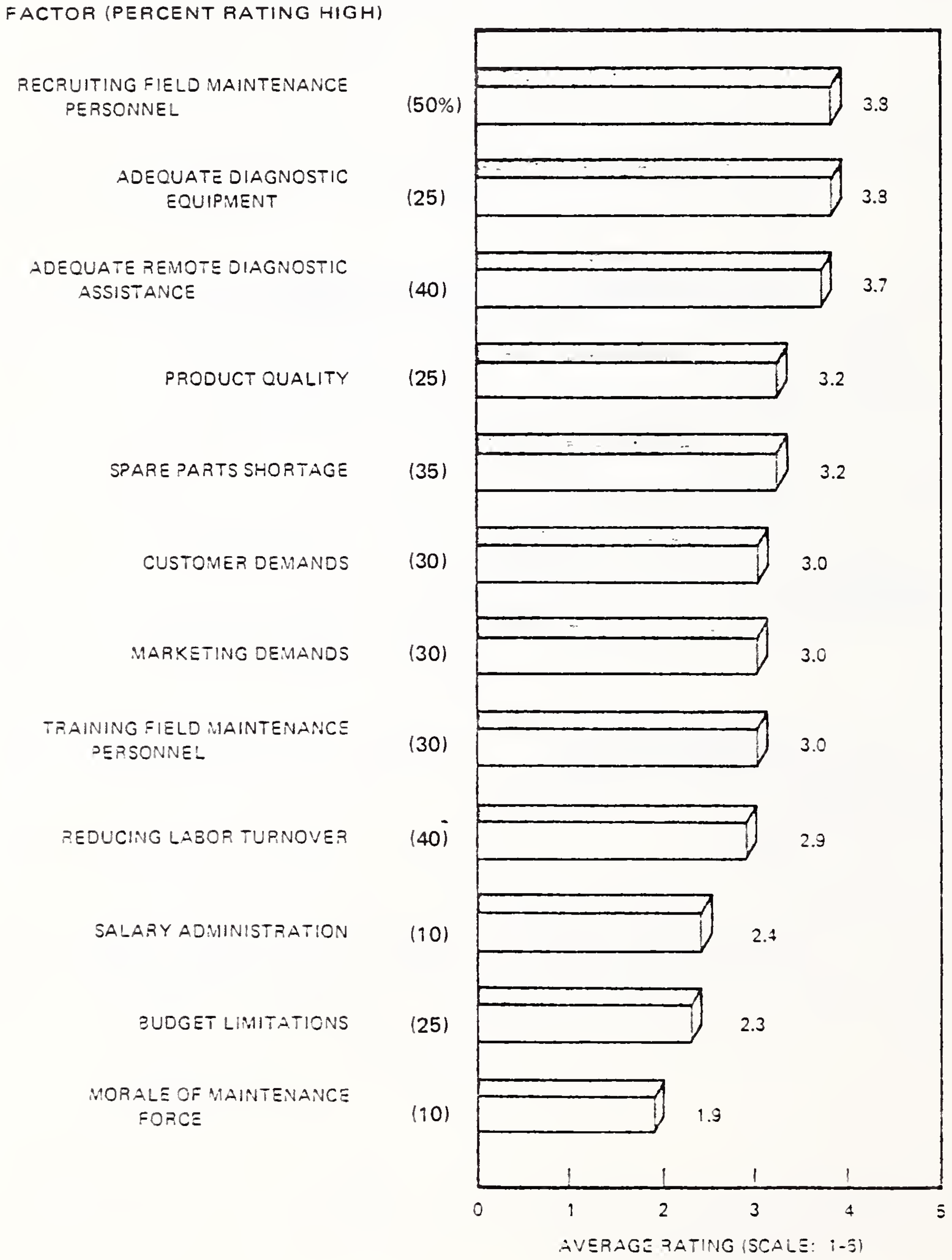


EXHIBIT V-5

VENDOR RATINGS OF PROBLEMS RELATED TO FIELD SERVICE



NUMBER RESPONSES: 20

EXHIBIT V-6

VENDOR RESPONSES TO EQUIPMENT AVAILABILITY

EQUIPMENT TYPE	AVERAGE UPTIME		MTBF		MTTR		AVERAGE RESPONSE TIME	
	RESPONDENTS	PERCENT	RESPONDENTS	HOURS	RESPONDENTS	HOURS	RESPONDENTS	HOURS
MAINFRAMES	8	95.3%	6	1,187	8	2.56	7	1.26
SMALL BUSINESS MACHINES	10	95%	7	2,164	10	3.08	9	3.17
MINI-COMPUTERS	6	96.4%	5	2,204	6	2.00	6	3.18
PERIPHERALS	6	95.9%	5	3,548	6	1.78	6	1.78
TERMINALS	8	95.6%	6	5,187	8	0.98	8	3.48

- The highest nonredundant mainframe MTBF reported was 2,500 hours, the lowest was 144 hours. The average MTBF for all mainframe vendors came to 1,187 hours.

- Terminals have the greatest unit reliability as reported by vendors (5,187 hours MTBF), and the shortest repair time.

- Reliability of peripherals is distorted somewhat by two vendors reporting over 6,000 hours MTBF. The norm is running 1,500 to 2,500 MTBF on peripherals.

- Small business machines are experiencing the same reliability as their forebears, the minicomputers, with the average MTBF reported as 2,164 hours. Average availability is pushed down to 95% in small business machines due to the slower turnaround of over six hours.

- The "average uptime" column in Exhibit V-6 is an average of averages which will not reconcile against average MTBF and average outages. Response times plus repair times do not add up to outage, which must be used to calculate availability.

- All 20 vendors (from a previous study) reported that field engineers replace boards on-site to effect repairs, and that they will continue this practice in 1984.

  - A greater number of respondents (11 of 20) indicated that their field engineers will be replacing units on-site in 1984.

  - Only four of 20 respondents have their field engineers replace components on-site, but six vendors expect field technicians to replace components on-site by 1984.

- Ninety percent of respondent vendors return most boards and units to a factory for repairs.

  - One-half of the vendors surveyed repaired some boards and units at a regional depot.

  - Only 10% of the respondents repaired boards and subassemblies on-site.

- Most system support centers are transparent to customers as reported by vendors, with only two vendors giving direct assistance to users from the support centers.

  - Although 11 vendors (55%) reported system support centers in existence for up to 11 years, the concept of direct user access is relatively new.

  - Seven of the eleven system support centers are set up to provide software support to the field. This presents an opportunity to create more direct lines of communication with users as resistance to the concept recedes.

  - Vendors and users alike seem to feel that more selling and proving of the benefits of direct user interface with system support centers are in order.

    - Users have indicated their strong feelings about losing the "personal touch" and about paying for maintenance to be performed for them.

    - Vendors feel a level of user resentment and continue where possible to interface through a local maintenance person when providing assistance.

- For vendors with field forces greater than 200, system support centers use from 1% to 5% of available personnel. The two smallest vendors interviewed placed approximately one-third of their force in the centers, most likely reflecting a desire to get greater client coverage from a limited number of people.

- None of the vendors reported an increase in personnel due to the implementation of system support centers.

  - Eighty-five percent of respondents indicated that there was no discernible effect on total personnel requirements resulting from system support centers.

  - Except for one vendor who reported a personnel savings of 84%, decreases in total personnel ran at 5%.

- Four of the nine respondent maintenance vendors without system support centers planned to implement the concept between now and 1985.

  - Two of the four expect to save 15% in personnel requirements as a result of implementation.

  - Five vendors (25%) have no current plans to implement system support centers.

- High reliability technology at more reasonable rates is beginning to have some effect on the volume of equipment that may be handled per field engineer, but the ratios of utilization are not impacted.

- User involvement in diagnosing and solving problems offers some potentially dramatic relief at the bottleneck, but draws little attention from vendors. INPUT forecasts an increase in the level of user involvement in maintenance as IBM and other vendors promote the concept.

  - Customer involvement in maintenance and diagnostics will elevate the importance of remote technical support techniques as customer personnel are expected to interface and implement solutions suggested by computer vendors.

  - The inevitable evolution of user involvement will place a new burden on the training department to provide the field with well-documented training aids for users.

- Half the vendor respondents consider improvement in product price/performance ratios to have significant impact on maintenance techniques, as shown in Exhibit V-7.

  - Maintenance costs become much more visible to the user as price/performance improves.

  - A selling point suggestion is to relate maintenance prices to performance (throughput) instead of units or unit prices.

- Vendors perceive technological advances to have medium to high levels of impact on maintenance.

  - Upgraded training requirements become more frequent with new technologies.

  - Higher reliability with less frequent failures means slower learning curves and longer mean times to repair.

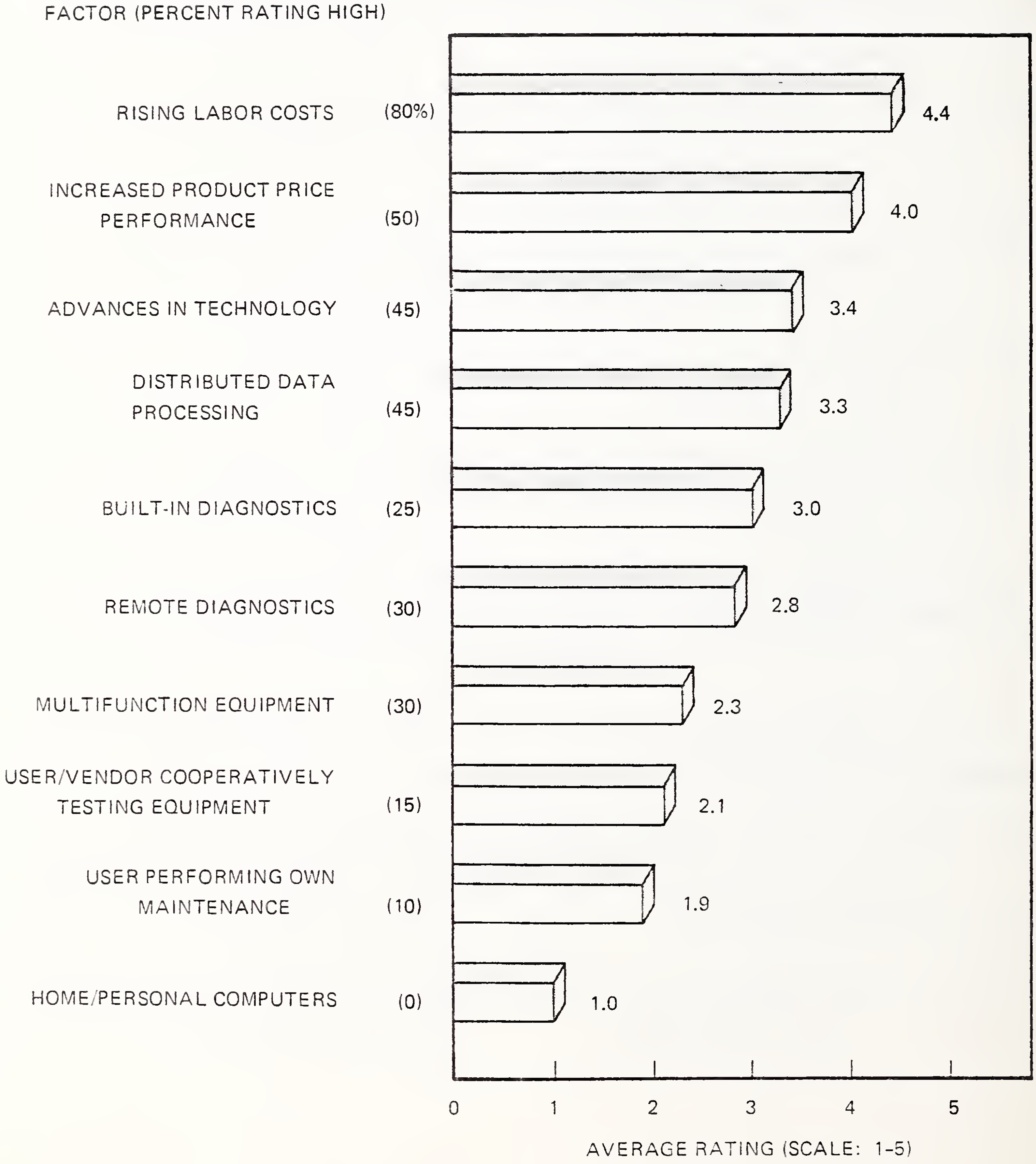
  - Better price/performance creates higher visibility to users of increased maintenance ratios.

- Distributed data processing (DDP) was rated highly as having an impact on maintenance techniques by 45% of respondent vendors (from a previous study), as shown in Exhibit V-7.

  - The dispersed characteristic of DDP is causing some concern about the focal points of service.

EXHIBIT V-7

VENDOR RESPONSES ON IMPACT OF FACTORS RELEVANT TO MAINTENANCE TECHNIQUES



NUMBER RESPONSES: 20

  - Innovations like remote diagnostics will most likely be pushed to the foreground by DDP maintenance vendors over the next few years.

b. Layaway Approaches

- Maintenance service vendors have had little experience with dormant systems.

  - Their main function is to keep systems running.

- They have had some experience with storage of spare parts for varying periods of time up to about three years.

  - No significant degradation occurred to belts, wheels, gaskets, seals, etc. during this short period. These items were stored in sealed plastic bags.

  - Those electronic parts such as boards and ICs, which passed the initial testing that was performed when they were received, survived two to three years of storage with no signs of corrosion that might have affected their performance. These parts were kept in the original shipping container or in sealed plastic bags.

- The service vendors suggest that systems be left "on" in some idling mode when they are not in use.

  - When reminded that the period under discussion could be 15 to 20 years long, the approach was modified. Systems stored for that period would have to be cycled periodically. It would be best if the system were left "on" in an idling mode for about one month out of each year or two of dormancy.

  - It must be remembered that this suggestion is not based upon "hard" data but upon a "feel" for the situation coming from years of maintenance experience.

- The service vendors feel that the reactivation of the system at annual intervals could serve as the preventive maintenance effort.
  - Belts and wheels that have developed sagging or bumps due to storage in a particular position should be replaced before the unit is powered up.
  - All equipment should be eye-checked very carefully for loose boards, loose chips, and any other anomalies.
  - All units should be powered up slowly, allowing capacitors to reform, and power supplies to warm up before being asked for top performance.

3. OTHER VENDORS

- Other types of vendor can make a contribution in the maintenance area. Time permitted contacting a representative of each of only three types of vendor. Additional tasks should be undertaken to:
  - Find other vendors in these specific fields.
  - Find other specific industries that can make contributions toward the long-term maintainability of these systems.
- Two of the three vendor's products or services deal with maintenance and will be discussed here.
  - The third vendor's endeavors are in the training field and will be discussed in Chapter VII.
- Anticorrosive coatings have been used by the military for long-term protection of a variety of equipment for many years. The type of coatings used usually required extensive de-coating work before the equipment could be used.

- Such coatings are not very useful when storing electronic components due to their small size and the danger of damage when handled, both in applying the coating and removing it.

- Anticorrosive vapors have been used to protect electrical components while in use and in storage.

  - A potentially useful new product, introduced in 1978, called ZERUST®, is manufactured by:

    - Northern Instruments Corporation
      6680 N. Highway 49
      Lino Lakes, MN 55014
      612-784-1250

  - The ZERUST® user that was interviewed found the product to be very effective for use in storing metal construction materials used in nuclear power plants.

  - The user stated that Northern Instruments' claims are understated, that Northern Instruments was technically honest and very cooperative during the user's testing program.

  - Tests related to ZERUST®'s use with integrated circuits and other electronic and electrical components are included as Appendix E.

  - INPUT has seen no tests to indicate that the molecular vapor coating on the IC pins can be penetrated by the extremely low current used in modern microcomputers and other ICs. If the coating cannot be penetrated when the system is reactivated after a long inactive period, then the coating will have to be physically removed, an undesirable activity.

  - ZERUST® comes in vapor capsule form. The capsule is placed in an enclosure that is circumscribed but not sealed. The vapors will permeate and protect all metal surfaces.

  - ZERUST® is also available as a plastic bag. The bag has an outer impermeable layer and a permeable inner layer. Between the layers is the protective vaporizing compound, as shown in Exhibit V-8. These bags are useful for storing spare parts and subassemblies. Very large bags can be used over whole cabinets.

  - There are other anticorrosive vapor compounds available, but non-exhaustive research indicates that ZERUST® is a superior protector.

- There are companies that specialize in the repair of electronic components. Some of these companies will produce boards for short production runs if the boards are no longer available from the manufacturer.

  - These companies do not provide maintenance, they provide only repair services.

- The largest of these independent companies

  - PSI Electronics, Inc.
    11900 Mayfield
    Livonia, MI 48150

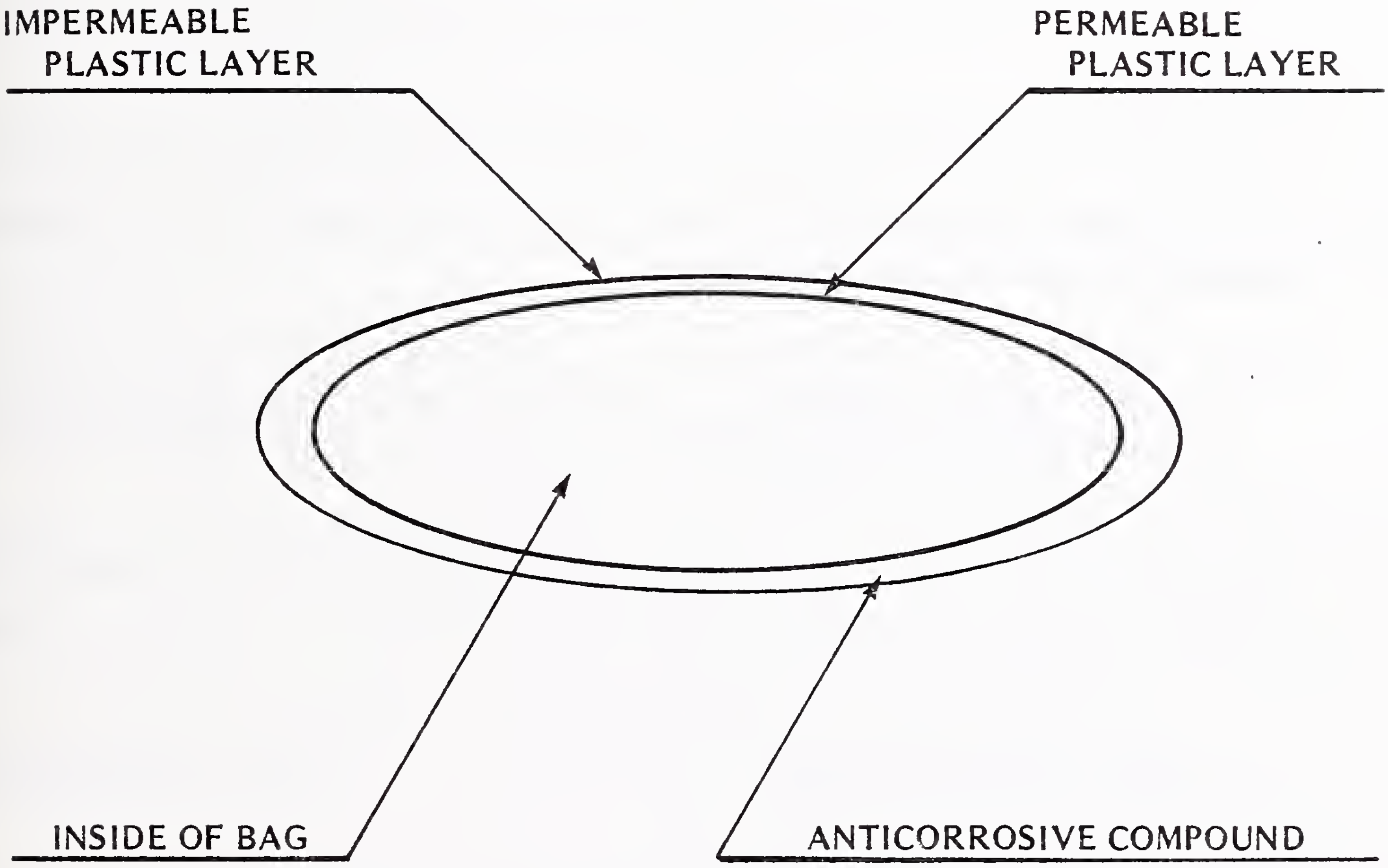
  has five service centers across the country.

  - PSI will store a set of board drawings so that repairs can be completed in minimum time.

  - PSI will participate in a parts exchange program in a crisis. It offers a six-month operating guarantee.

EXHIBIT V-8

ZERUST® ANTICORROSIVE PLASTIC BAG



  - PSI specializes in the repair and conversion of obsolete components.

  - PSI has competitors. The major third-party maintenance companies use other repair and parts production shops when necessary. In the short time spent researching these companies, PSI was the only nationwide firm uncovered. Additional detailed research is required in this area.

C. USER ANALYSIS

1. SYSTEMS

- The users interviewed used electronic systems in a wide variety of control applications, as shown in Exhibit V-9.

  - The processes ranged from control of a single item such as electric power to the complete control of an entire film production line.

- The systems about which information was gathered included 15- to 20-year old computers, as well as some currently being installed.

  - The major process control system manufacturers were represented, as shown in Exhibit V-10.

  - The newly installed systems in all cases were replacing older systems. Existing systems were frequently undergoing enhancements while they were still controlling the process. The addition of more control points (sensors and actuators) was the usual form of expansion. Programmable controllers were being added to control the new sensors and actuators in order to lessen the burden on the procesor. This prolongs the life of the control processing system.

EXHIBIT V-9

TYPICAL USERS INTERVIEWED

INDUSTRY	APPLICATIONS
CAMERA AND FILM MANUFACTURING	AUTOMATIC FILM PRODUCTION
CHEMICAL PRODUCTION	SULPHURIC ACID BURNER CONTROL TETRAMETHYL LEAD MANUFACTURING
INSTRUMENT MANUFACTURING	CHEMICAL PLATING PROCESS
PETROLEUM REFINING	CRUDE OIL PROCESSING CHEMICAL MANUFACTURING
PHARMACEUTICAL MANUFACTURING	GELATIN CAPSULE PRODUCTION
POWER UTILITY	GENERATOR DEMAND CONTROL PLANT MONITORING
STEEL PRODUCTION	ELECTRIC POWER DEMAND MONITORING AND CONTROL CONTINUOUS CASTER FURNACE CONTROL

EXHIBIT V-10

PROCESS CONTROL SYSTEMS AT USERS' SITES

VENDOR	SYSTEM
ACCUREX	PROGRAMMABLE CONTROLLERS
ANALOG DEVICES	MAC SYM 2
BECKMAN INSTRUMENTS	MV8000
CONTROL DATA CORPORATION	CDC 1700
DIGITAL EQUIPMENT CORPORATION	DEC II SERIES, DEC LSI-11
FOXBORO	PCP-88
GENERAL ELECTRIC	GE 3010, 4020, LOGITROL
HEWLETT PACKARD	HP 1000
HONEYWELL	H316, H716, H4500
IBM	IBM 1800
LEEDS AND NORTHRUP	L&N 3000
LOCKHEED	MAC 16
MODULAR COMPUTER CORPORATION	MODCOMP II
MODICON	PROGRAMMABLE CONTROLLERS
TAYLOR INSTRUMENTS	MOD 3
VARIAN	620
WESTINGHOUSE	P250

  - This increased distribution of control and the use of a hierarchy of systems tends to increase the MTSF without having redundant hardware throughout the system.

- The largest system controlled the manufacture of photographic film. Currently, 8,000 I/O points are monitored and controlled using about nine systems. The goal is to monitor and control about 30,000 I/O points, then raw materials will enter at one end of the plant, and packaged film in a sealed box will exit at the other end.

- It is very curious that systems were installed at the end or beginning of a decade. Only two within the small sample were installed in the middle of a decade.

Year	Number of Systems
1958-1961	2
1968-1969	5
1973-1975	2
1978-1980	6

  - Systems generally were operating within a comparatively short time after procurement. The longest cycle was three years, with most systems operating within two years.

2. SOFTWARE

- Users formed a symbiotic relationship with the primary EPC system vendor with users being actively involved in all phases of the design, equipment selection, installation and especially software efforts.

  - Vendors supplied the operating system, but the user in conjunction with the vendor usually programmed the application.

  - One user collaborated with an outside software house for custom software.

  - One user who very strongly believes in giving total maintenance responsibility to the vendor, accepted the vendor's special process control language in order to discourage custom software and ensure the vendor would maintain it.

- Software documentation is felt to be generally complete and up-to-date if the vendor supplied the software.

  - When the user programmed the custom applications, the quality of the documentation was a function of the documentary ability of the language and language processor used.

3. SYSTEM BACKUP

- Seven users had backup systems that were redundant and, therefore, were ready to go in case of failure of the primary system.

  - The three users that had only manual backup systems all expressed a fear that the manual system skills will be lost soon because the EPC system is so reliable.

  - Analog backup systems represented a halfway point between computer and manual controls.

  - One user is relying on the self-diagnostic capability of the CPU to provide the reliability necessary, and backup is limited to disk drives and interface controllers.

- Programs are stored generally on magnetic media and are kept in multiple fireproof locations.

  - Few users kept up-to-date copies of the program on fixed media such as paper tape or punched cards until the programs had run long enough with few changes to assure people that new cards or paper would not have to be produced regularly.

- Fail safe considerations varied considerably depending upon the danger to people at the plant if the process "ran away."

  - Danger monitoring systems are rarely designed for worst case because a considerable quantity of extra equipment is involved. The economics dictate a certain amount of risk-taking.

  - In one case the extra equipment has been dismantled because the system has proved to be very reliable.

- The CPU is usually wired to all I/O control points, to the alarm system, and to the fire protection system.

  - The CPU has an uninterruptable power supply and, in one case, the CPU memory has a 70-day battery backup.

4. SUPPORT

- The best vendor support can be obtained by restricting the installation to only one vendor.

  - Many users became very involved in their systems primarily to avoid having to bring in another vendor.

  - While support has been good, some users feel the most consistent support can only come from within the company and, therefore, they have become almost totally self-sufficient. These users still rely heavily on their single vendor for all types of support, including hard to find competent people.

- Support contracts where both parties are fully aware of each other's responsibilities is a commonly found approach.

- The older the system, the more wary the user, and the more the user depends upon his own resources. Also, over the years this type of user has seen many vendors and may now have expanded the initial process control system so that many vendors are or have been involved. Much finger-pointing can be avoided and time saved by building a strong in-house capability when a multivendor situation exists.

5. RELIABILITY

- The experience of the respondents can generally be classed as very good. Systems are running well especially after the initial burn-in period. Uptimes of 99.5% and 99.8% were reported for the CPU. Some comments from the users illustrate their confidence in their systems:

  - "First installation in 1978 and have had two hardware failures since."

  - "Hardware performs very well."

  - "No startup problems and no major failures."

  - "Very good reliability history. We no longer keep a failure log - it gathered dust."

- Not everyone was so happy. Peripherals presented problems from the start on some systems.

  - "Selectric printer gave most problems."

  - "Nixie tubes burn out after a few years."

  - "Peripherals and analog scanner gave us plenty of problems."

  - "CPU is up 99.5% of the time, but the disk drives always seem to be down."

- A daily log is used as a failure report by most of the users. Since most users have maintenance contracts with vendors, it is the vendor's responsibility to do the more serious reporting and tracking of failures.

  - One user gave up the failure reporting system ten years ago because "We became recordkeepers instead of engineers."

  - Two users completed the feedback loop and analyzed the failure reports in meetings between vendor and user managements. The information was used in decisions on equipment replacement.

- Users do not concern themselves with MTBF, MTTR, and other system statistics. If the vendor has maintenance responsibility, the user just wants the system to run 24 hours per day.

6. MAINTAINABILITY

- The maintainability of systems is not a significant factor in the design of EPC systems. However, the most experienced user interviewed did claim that systems with poor reputations for maintainability would be rejected.

  - The most prevalent design feature that the installed systems have to ease the maintainability problem is built-in self-diagnostics. Usually the respondent was not aware of how much the self-diagnostic features of the system contributed toward its selection.

  - As memory prices decrease, more users are adding sufficient memory enabling the use of on-line diagnostic software which continuously tests the various components.

  - Modular system design permits the pulling of malfunctioning components without shutting the system down and replacing those components with a spare. The bad component is repaired and replaced in the system or sent to spares inventory.

- EPC systems are frequently crucial components of a production process that runs 24 hours per day, 365 days per year.

  - This expected performance, users feel, justifies the expense of a maintenance contract with the vendor that calls for a vendor's field engineer resident at the customer's site.

    - One user who pays for a vendor's field engineer on-site for eight hours per day, five days per week is planning on increasing this service to 24 hours per day, seven days per week in spite of the 200% increase in maintenance cost.

- Preventive maintenance is usually limited to peripheral equipment; however, few users will tolerate that fairly low level of PM if they have a resident FE.

- PM frequency is planned as a function of the particular system and the process under control.

  - PM on a per month basis is the norm among the interviewed companies.

  - At one company's site, PM was originally performed weekly and gradually set back to monthly, based upon experience. At another site, PM was scheduled on a quarterly basis but the system had a chronic problem. Accelerating maintenance to monthly cleared up the problem.

7. PERSONNEL

- The users that had long-term maintenance contracts with the vendors were not concerned about the vendor's source for personnel. The user was concerned that the FEs sent to work on the system were trained not only by the vendor generally but in the specific hardware.

  - The most important skill a maintenance engineer can have is the ability to troubleshoot - to logically diagnose. Repair can be done by less skilled people. Many users felt that troubleshooting skills are innate, and the training provided merely enables the engineer to develop specific talents.

- Users prefer to hire from within, but as skilled personnel become increasingly scarce, recruiting policies change to meet the situation.

  - Users are now looking for trainable people and are putting extra dollars into the development of extensive training programs. Packaged video courses are increasing in popularity because it becomes economical to train individuals, geared to the student's own learning rate.

  - User training programs are frequently designed to bring the student up to the level that the vendor will accept in the vendor's training program.

- The usual sources of personnel mentioned by the respondents were:

  - Military.

  - Competitors.

  - Technical schools.

  - Off the street.

8. SPARE PARTS MANAGEMENT

- Only one user had a spare parts management approach that was called a system even though it was an ad hoc development. Some important elements of the approach are:

  - Buy spares through judgement and experience. Do not rely entirely on the vendor's list.

  - Keep track of the time each part is in the system. Replacement time is very important. Parts should be replaced before they go bad. For example, electrolytic capacitors go bad after ten years. They should be replaced at nine years.

  - Keep track of alternative sources of supply.

  - Keep track of supply depots.

  - Remember that a dual system inherently has spares.

  - Test all spares as they are received.

  - Store spares in an environmentally controlled area near the computer. If possible, store in a rack as if in a system.

- Most respondents with vendor maintenance do not have any spares inventory on hand that they own. The vendor keeps and maintains the inventory.

  - No value level pattern could be found among those users that kept inventory on hand. The values cited were:

    - $150.

    - $500-600 (for five systems).

    - $30,000.

    - $120,000.

    - Fifteen percent of the installed value of the system.

    - A spare system (in storage).

- The user with the $150 inventory does not believe in tying up money in inventory. The factors influencing this conservative decision were:

  - Warranties.

  - Maintenance contract.

  - Reliability.

  - Self-diagnostic features.

  - System redundancy.

- Storage conditions for spares varied widely from a clean room with foam-padded drawers to an ordinary file cabinet on the factory floor.

  - Frequently, the spares are stored in the original shipping containers.

  - One user who extensively tests the new spares began the program on a regular basis because at one time fully 50% of the spares were defective.

- Spares are not usually guaranteed beyond three years, although with proper storage, one user claims parts have been stored for 20 years.

- Maintenance contracts usually specify that the vendor will retrofit the system with the latest parts so that the system does not become obsolete.

  - Users plan on replacing their systems when vendor support and/or parts are no longer available.

  - Vendors have promised to support the system for a minimum of five years, and some vendors have promised ten years.

9. DORMANCY EXPERIENCES

- Six of the responding vendors had some occasion to turn their system off from the process for varying periods of time. Since the experiences vary greatly, each case is described separately below.

a. User 1

- System 1.

  - The system was shut down about ten months ago. The manufacturer is no longer in the computer business and parts are not available. The system is unprotected and sits in the middle of a closed factory building. It has been totally abandoned. The user will probably never use the system again.

- System 2.

  - The system was disconnected from the process in December 1979 due to lack of business. It has been kept running all the time because the user is afraid to turn if off. The system is idling. The system is dusted off and occasionally used for debugging new programs. The system will remain in this state until business picks up.

IN

b. User 2

- The longest dormant period was three months due to a decrease in production. All units are kept "on" now during dormant periods. Earlier strategy was to turn them off, but this caused the operators to forget to turn them on when reactivation was necessary. In order to reduce the loss of time due to forgetting to turn the control units back on, the units are now wired for continuous "on" operation.

c. User 3

- The system was powered down, but the computer room atmosphere was maintained. The dormant period lasted about nine months. Upon reactivation, the contacts on the boards were corroded slightly. Rubbing the contacts and reseating the boards cleared up the problems. Overall experience is considered good.

d. User 4

- The plant was closed for six weeks and the system just turned off. The computer room was kept cool and I/O sensors were stored carefully. Reactivation was "horrendous" due to user "sloppiness" not because of the system. Problems encountered included warped boards, misaligned boards, dust, electrical shorts, and moisture.

e. User 5

- Systems stored for two years were covered with plastic bags and kept in a heated warehouse. Magnetic tapes and disks were stored in a humidity-controlled area. Upon reactivation, the units were dusted, vacuumed, and thoroughly inspected. They were turned on according to the vendor's instructions for new installations, and there were no major problems. Power supplies were the most sensitive component.

f. User 6

- Process was shut down in January 1981 but all control systems are kept running, with applications software, except for the sensors. The system is still in the same state as of this writing.

VI SPARE PARTS MANAGEMENT

VI SPARE PARTS MANAGEMENT

- This chapter corroborates the general information obtained from the interviews with information from other INPUT studies.
  - Hard interview information was sparse because the vendors felt that their practices were geared toward different goals than a customer would have. The users' interviewees did not have specific management practices that were codified such that they could be delineated easily for passing on as advice to others.
  - Practices were ad hoc for the most part among all users interviewed including the ammunition plants. The ammunition plant information can be found in Chapter IV. User and process control vendor information is in Chapter V.
- Spare parts management should be appropriately addressed whether or not the user has a maintenance contract. Maintenance contracts currently obligate the vendor with total logistics (parts) responsibility. Customers without a maintenance contract must consider purchasing a recommended list of spares.
  - The goal of inventory management is to satisfy the need for necessary parts and supplies, with attention to control of the inventory and its costs.

  - Inadequate, or worse yet, incorrect inventory will result in dissatisfaction due to the weakened support capability. Such situations force everyone involved to divert their attention and energy toward resolving a parts situation that should not have occurred.

  - Inventory considerations are a major part of the support function, whether or not the support comes from the vendor or the customer.

- Inventory costs are a major consideration, since inventory on hand is increasing in value due to higher replacement costs and demand.

  - Packaging, shipping, handling, testing and repair can cost as much as 25% of the retail price for a given part. Parts of less than $25 value are normally expendable.

  - If inventory levels permit, the first-in-first-out (FIFO) method should be used. This will minimize the cost factor as well as potential shelf-life problems.

- Technological advances through continued research and development will impact the inventory process. Theoretically, improvements in equipment reliability will lower the required spares levels.

  - Whenever a customer upgrades the system to a later design, the supporting inventory should be upgraded as well.

- Once inventory objectives are established, they must receive full support from all responsible parties.

- The customer must learn how long the product will be supported after production terminates. Armed with this knowledge, the customer can develop long-term strategy for inventory requirements.

  - Individual customer apprehensions over "recommended" spares will also impact the type and level of customer-owned inventory.

  - Recommended inventory usually represents 10% of the equipment purchase price.

  - Inventory purchase after production has stopped will be expensive even if drawings and tools are retained. Replacing parts will require manufacturing resource planning in a custom mode.

  - This would be true also if the customer had the appropriate artwork to support manufacturing at a third-party source.

- The vendor has no obligation to maintain a customer's inventory to current revision levels. One way of being kept informed of revisions is for the vendor to place customers on the mailing list for all engineering and/or field changes for their particular hardware.

  - Typically, not all design changes will alter the basic operation of a device or system, so it is not necessary to upgrade a customer's inventory with each change.

  - Major changes, however, that will alter the operation of a device or system compel the customer to consider adopting the latest revision of that particular subassembly. This is usually done at a reasonable cost.

- The useful life of most spare parts is at least five years. Any investment necessary to maintain them at current revision levels is justified, as well as time spent for periodic testing.

- Inventories should be consolidated as much as possible, consistent with providing a timely supply. Elapsed time will be shortest when parts are easily accessible.

  - Parts with the highest usage and frequent turnover should be located nearest the equipment location.

  - Parts with the least usage and turnover can be centralized or ordered as required. Vendors will usually respond within 24 hours.

- Vendor inventory management is usually very sophisticated. Large vendors track inventory in a real-time mode using a computerized system. If a part is unavailable locally, management is then capable of locating it (nationally) and arranging its shipment immediately.

- Smaller vendors without a computerized tracking network are usually no more than three days (mail) behind current inventory status. More often than not, they can perform just as efficiently when locating a needed part and shipping.

- Periodically, vendors find it necessary to "shake-out" inventory that has been "accumulated" by FEs. This is particularly true of defective parts.

  - During unusually busy service periods, it is not uncommon for FEs to change their priorities and delay the return of defective parts to the repair cycle.

  - It is critical that the flow of these defective parts continue through the inbound "pipeline" so they may be repaired and returned to the outgoing "pipeline."

  - The human element is critical to any inventory control system.

- Inventory control is a very complex issue, consisting of many elements such as correct part number identification, correct replacement (direct) part number identification, order communications, availability, integrity of the parts performance, shipping and packing, return of the defective part if not an expendable item, and debit or credit of inventory level.

- Vendors, as well as customers, must assume a degree of risk for "out of stock" items. Economies of scale simply do not make it practical to be in a position to fulfill 100% of all needs.

  - Consider that even a success of 95% leaves 5% failures.

  - A/B/C Analysis, also known as "The Principle of the Critical Few and Insignificant Many," "Pareto's Law," and the "80-20 Rule," helps direct attention to the most important items.

  - Pareto's Law suggests that, regardless of inventory ordering criteria, the distribution of parts on a percent basis will remain the same.

  - An 80% service level can usually be met with less than 20% of all field replaceable parts. A 90% level has been observed with only 10% of the possible replacement parts in stock, correctly chosen in proper quantities.

- Once inventory requirements and levels are established and satisfied, vendors will satisfy internal needs and customer needs in accordance with an operational priority code. It would be appropriate for customers to establish a similar code. The intent is to sensitize the logistics function to all situations.

  - Typical operational priority codes are:

    - Priority 1 - Customer has experienced a catastrophic failure requiring necessary parts immediately. If the part is not available locally, it must be located and placed on the next available flight, while the FE stands by to pick it up and satisfy the problem.

    - Priority 2 - Customer equipment is down, but not hampering any critical phase of the operation. If a part is not available locally, it must be located and made available within 24 hours.

    - Priority 3 - Customer equipment may or may not be down. There is, however, a marginal or intermittent problem. If the part is not available locally, it can be ordered, processed, and shipped routinely. Elapsed time from receipt of order is typically five days.

- In conjunction with these operational priority codes, equipment and selected parts are coded in order to attach an appropriate degree of importance to the device or part. Priority 1 indicates the highest priority.

  - Typical examples are a microprocessor would be a 5, a CPU board within the microprocessor a 4, a modem 3, keyboard switch 2, and indicator lamp 1.

- The combination of the operational priority code and part rating allows a rapid calculation of the action to be taken in response to any situation.

  - The rating number should be assigned to each part by maintenance management with the concurrence of inventory planning.

  - Attention should be paid first to all 5-rated parts, then 4s, 3s, 2s and finally 1s. If the inventory budget is restricted, it should be invested first in all the needed 5-rated items, working down in priority on lower rated items until the money supply is exhausted. This could mean that no 1 or 2 items are stocked; but the effect on system operation should be minimal.

- Flexibility is important to spare parts inventory management since more than one source can often be used to solve a parts storage problem. This involves an ability to determine where the needed part might be among several different locations. In addition to getting a part from inventory, the use of the next higher assembly, borrowing from other products the part is used on, or even cannibalization can provide emergency alternatives.

- Inventory and maintenance personnel often go to extreme efforts to get parts necessary to repair the system.

    - Managers must be alert and not allow these special efforts to become the norm.

    - Emergency parts requisitions exceeding 10% of total requisitions are a sign of poor inventory management.

- Customers should review fundamental inventory planning parameters with the vendor. For any given system, these levels should complement the system configuration.

    - Although the "recommended" spares list is a necessary tool for planning and control, real life experiences should be used to change the "recommended" spares list accordingly.

    - Parts not requiring heavy usage can normally be traded off for parts of higher usage. Any difference in their dollar value will be debited or credited.

    - The major reason for overstocking parts is a lack of confidence in adequate, timely resupply.

        - Minimum downtime results if maintenance has the part or can get it within, for example, one hour.

    - Standardization is important. Not only are fewer parts required and costs lowered, but also the need for training, tools and manuals is reduced. Program management must ensure that tradeoffs between maintenance requirements and those of accounting and engineering are well defined and understood.

  - Stock lists should be established based on nearby similar systems and special conditions.
    - These parts are identified by maintenance personnel, as discussed earlier, and quantities are established in cooperation with inventory planning.
    - Cooperative efforts among operating contractors with similar systems should be encouraged.
    - Maintenance personnel often consider the use of stock lists extremely restrictive, but experience shows that the lists are a necessary tool for planning and control.

- Carrying and holding costs include space, security, information, obsolescence, protection from damage, insurance and either the cost of money invested in inventory or the value of forgone investment in other alternatives.
  - Carrying costs will range from 20% for small, stable, low-value parts to 30% for electronic components that are more valuable and subject to obsolescence, theft and damage.

- Inventory classifications include working stock (on hand), pipeline (inbound and outbound), safety, and loaned.
  - Working stock (on hand) represents the stock in inventory and ready for use.
  - Pipeline parts are "in transit."
    - Inbound - defective parts being returned for repair.
    - Outbound - repaired parts returning to inventory.

- Safety stocks are extra quantity kept as insurance against contingencies.

- Loaned stocks are those being "temporarily" used at another location. They are expected to be returned or replaced.

- Parts in inventory should be capitalized until they are used.

- Inventory for new systems involves brand new equipment, very little history, some correlation with prior products, reliability predictions, some laboratory tests and, most importantly, people's best engineering experience and educated judgement.

  - Planning inventory for new systems requires input from the vendor's engineering, quality assurance, production, marketing and experienced field personnel. Initial stock-keeping unit (SKU) identification should be based on a part's expected failure rate. Reliability engineering can assist with failure modes, effects, and criticality analysis. Quantities are based on the location of stocked spares, lead times for resupply, essentiality, and cost. Experience with comparable, existing products is the best guide.

  - The need for adequate replacement parts as well as trained personnel, tools and information should force consolidation of early installations.

- Once operational experience is gained with the new systems (generally at about the six-month point), inventory of replacement parts may be assumed by the maintenance group.

  - Engineering changes, modifications, and new versions of equipment often cause subsystems to revert to initial provisioning techniques.

- The termination phase requires the acquisition of enough parts to support service needs as long as the products remain in use.

  - End-of-life planning for parts must take place when a product will no longer be manufactured or supported. Management must decide how long the system will be operated after support is terminated. Maintenance management and vendor's spares analysts must then forecast part demand during that period.

  - Additional purchases after support has stopped will be very expensive, even if drawings and tools are available, so the end-of-life spares purchases should be made during the last production run.

- An inventory control system must provide accurate information at all times. Knowing the location and availability of a part is critical to overall system performance.

  - This information can be maintained manually, or it can be computer-based.

  - Either way, the discipline and competence of the people maintaining the system are crucial.

- A manual system using a card for each SKU is very effective.

  - Personnel must be trained and controlled to make the appropriate entries whenever a part is removed or added to the inventory.

- Computerized control allows inventory records to be updated instantaneously. This will make inventory data available in a real-time mode without having to conduct a physical search on the premises, or elsewhere.

- A few fundamental but critical techniques relative to the handling of spares inventory become paramount. They include dating and storage.

- Most electronic parts have a shelf life of five years or more; however, it is necessary to date them, especially if the system is dormant.

- In the case of mechanical assemblies requiring some form of lubrication, dating will support a schedule of periodic examination and lubrication, as required. Without it, a frozen mechanical assembly will prove devastating at the time of installation.

- At the time the "recommended" spares complement is purchased, it is assumed that all the parts are new. Although all parts have been through a test cycle and quality control, the user should be concerned with "infant mortality."

- While it may not be necessary to test all parts in the inventory, a test program should be developed for selected critical parts.

- Examples of selected critical parts are CPU board, power supplies, print heads, disk drives, communications and interface controllers, and some cables.

- Once the system is installed and operational, a test program should be developed that would exercise these parts within the system for a period of time. This will satisfy the infant mortality concern by "shaking out" marginal or defective inventory.

- Once this has been satisfied, the confidence level of the inventory will be attained. Similar testing should be done for repaired parts returning from the vendor repair cycle, although there is less concern for a used part relative to infant mortality.

- Storage is equally critical. The first consideration is the proximity of the inventory to the equipment. This is important if elapsed time is to be kept to a minimum.

- Finally, environmental control for inventory is more critical than it is for an operational system, considering that the part may be "gathering dust" and aging while in storage.

VII PERSONNEL

VII PERSONNEL

- Information concerning vendor field service personnel is deemed of concern to ARRCOM and the operating contractors due to:
  - The use of vendor field service organizations at the ammunition plants.
  - The need for such personnel by the operating contractors who must compete in the open market for them.

A. VENDOR FIELD SERVICE ORGANIZATIONS

- Field service organizations are expected to grow steadily in the coming years, as shown in Exhibit VII-1.
  - Maintenance vendors' growth is expected to be greater than the growth forecast by the field engineering groups within system vendors' organizations.
- Field engineering turnover has compounded recruiting problems which had already become critical because of growth, as shown in Exhibit VII-2.
  - Nineteen of the vendors (from a previous study) reported hiring 3,706 field engineers to replace 2,316 for a net gain of 1,390.

EXHIBIT VII-1

EXPECTED INCREASE IN FIELD SERVICE ORGANIZATION SIZE, 1980-1982-1984

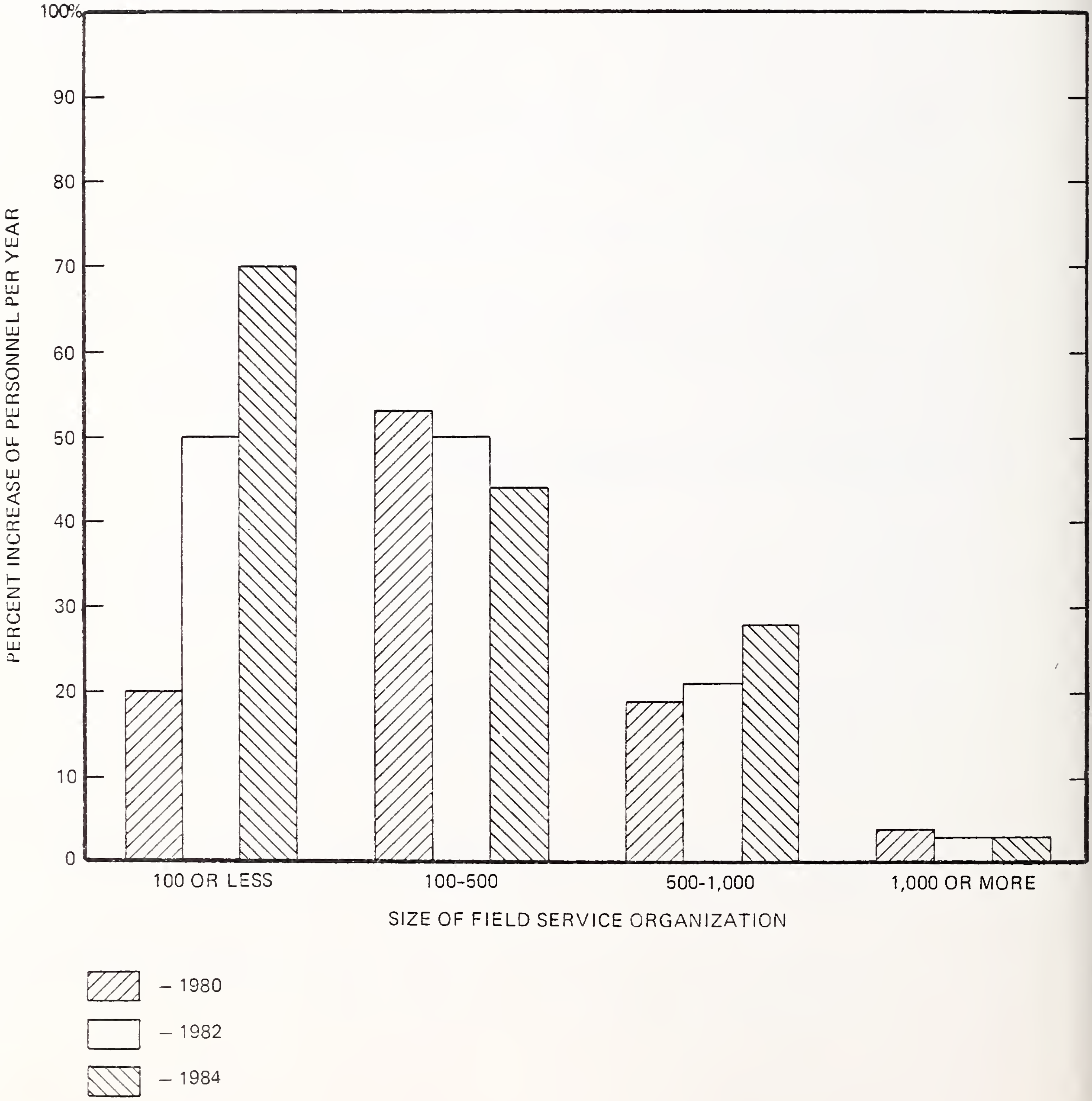
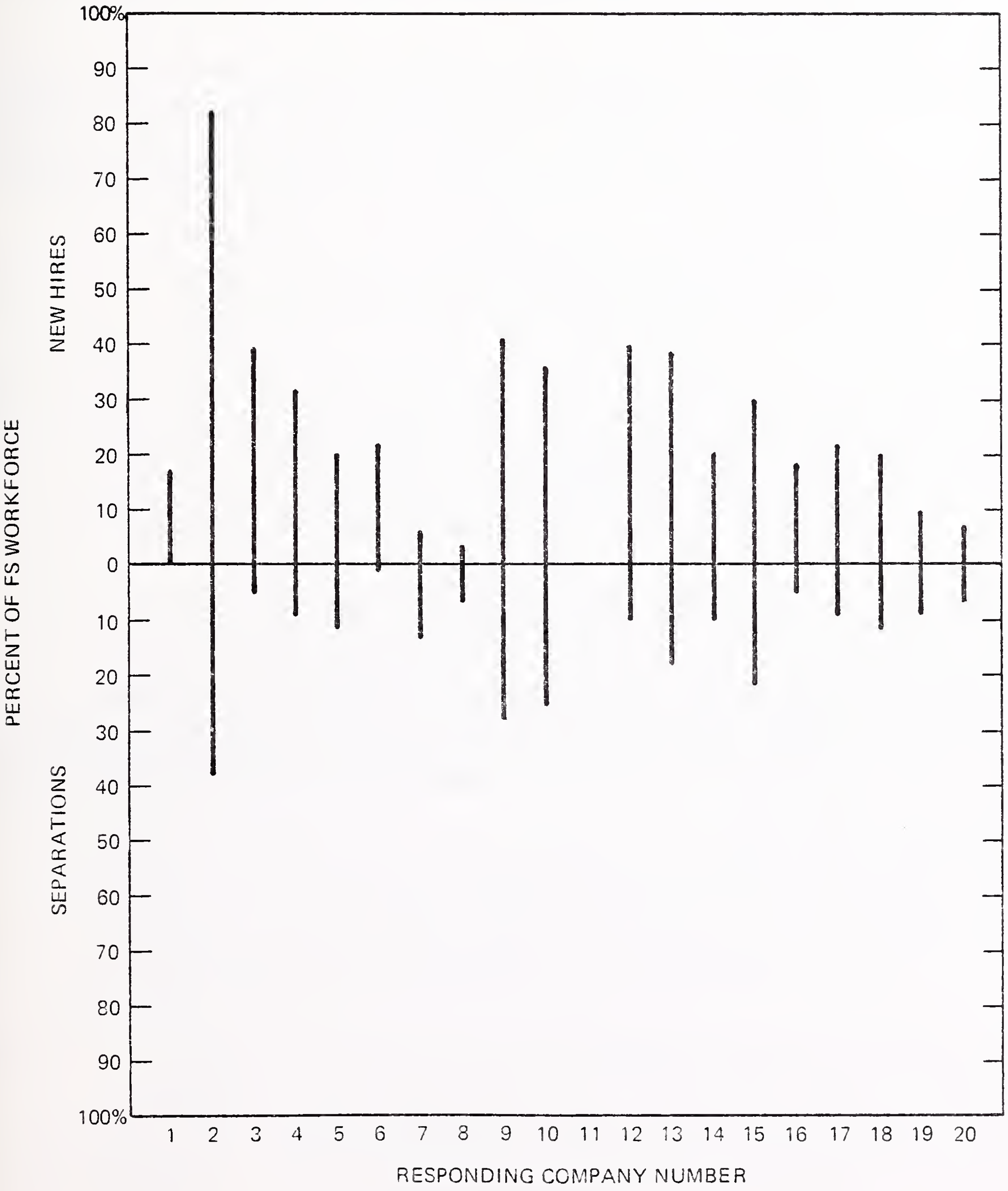


EXHIBIT VII-2

COMPARISON OF FE NEW HIRES AND SEPARATIONS - 1979



- Because of turnover, more new hires are required to gain employees necessary for growth.

- The average vendor hired 195 new field engineers to replace 122 for a gain of 73.

- Attrition was due to several familiar causes and some new causes as reported by vendors. Comments, some of which follow, ran 76% voluntary resignations versus 12% each for promotions and involuntary separations.

    - "Wanted to leave the area."

    - "More money."

    - "Career change."

    - "Move to warm climate."

    - "Spare parts not available."

- Many of these same reasons for attrition apply to the operating contractor's maintenance personnel also. In addition, the operating contractor is maintaining a dormant system in many instances, and this provides:

    - No challenge to maintenance personnel.

    - No chance to do an outstanding job justifying a promotion.

    - No justification to request or earn salary increases.

- In summary, then, the operating contractor's skilled maintenance personnel are in a stagnant, stultifying situation facing an extreme shortage of their skills in a marketplace eager to pay top dollars for their expertise.

- The trend toward trade schools as a primary source of new field engineers has become even more evident since 1978, as shown in Exhibit VII-3.

    - Eleven of the respondent vendors (55%) rated trade schools of great importance in 1980. In 1978, only 46% gave trade schools high ratings.

    - Trade schools were rated second in importance to recruiting from competition in 1978, but were projected into first place by 1982. This current survey finds trade schools already in first place, with only two vendors rating them of little or no importance in 1985.

- The traditional source of technicians - training the armed forces - remains in third place, with exactly 50% of respondent vendors considering this source as having little or no importance. By 1985, 65% of the vendors move the armed forces into last place by rating the source low or not applicable.

- Recruiting from competition, which ranked as the number one source of new personnel in 1978, has now slipped to second place, with 19 respondents rating competitive sources evenly from high to low in importance. Recruiting from competition moves into a virtual tie with the armed forces for last place in 1985, according to respondents.

- Respondent vendors give little importance in 1980 to hiring and training personnel with no technical background, but place this source very closely behind trade schools by 1985. Seventy-five percent of the respondent vendors rate this source of new field engineers as medium to high in 1985.

- Other sources of replacement or new-hires in field service include four-year degree schools as specified by one vendor. This vendor rated universities as high in importance both now and in 1985, and gave only low marks to all other sources.

EXHIBIT VII-3

RATINGS OF PRIMARY SOURCES OF NEW FS PERSONNEL

VARIABLE	YEAR			
	1978*	1980**	1982*	1985**
HIRE AND TRAIN (NO TECHNICAL PRE-TRAINING)	2.0	1.8	2.8	3.5
RECRUIT FROM COMPETITION	3.0	2.9	2.8	2.1
RECRUIT FROM INDUSTRIES	2.3	2.1	2.6	2.4
TRAIN DISCHARGED ARMED SERVICES PERSONNEL	2.6	2.5	2.4	1.9
RECRUIT FROM OTHER FUNCTIONS WITHIN THE COMPANY	2.7	1.9	2.5	2.2
TRADE SCHOOLS	2.9	3.7	4.0	4.1

(SCALE: 1 = LOW, 5 = HIGH)

*1978 & 1982 RATINGS FROM "MAINTENANCE REQUIREMENT FOR THE INFORMATION PROCESSING INDUSTRY 1978-1983"; SURVEY DONE IN 1978.

**1980 AND 1985 FIGURES FROM CURRENT SURVEY

NUMBER OF RESPONSES: 19

  - Another vendor rated universities as medium in importance now and in 1985.

  - The third vendor who specified a source other than those listed said that he rated two-year associate degree colleges medium in 1980, but very high by 1985.

- Field engineering trainees could be hired into base pay ranges from $4.73 per hour ($9,800 per year) to $1,900 per month ($22,800 per year). The actual base salaries paid to trainees by respondent vendors averaged from $12,000 to $20,220 per year.

- Base salary ranges for qualified field engineers on respondent vendor payrolls are from $12,000 to $25,800 per year. The actual salaries paid to qualified field engineers average from $15,000 to $23,000 per year.

- Annual salary brackets for senior field engineers range from $13,500 to $29,280 per year, and average from $17,000 to $26,000 per year.

- The relatively narrow range of salaries from trainee to senior field engineer shows little room for income growth commensurate with growth in capability; this fact undoubtedly contributes to turnover.

- Exhibit VII-4 provides a snapshot of the average salaries paid all field engineers by respondent vendors. The distribution of average salaries remains consistent from trainee to senior in all companies except numbers 7 and 8.

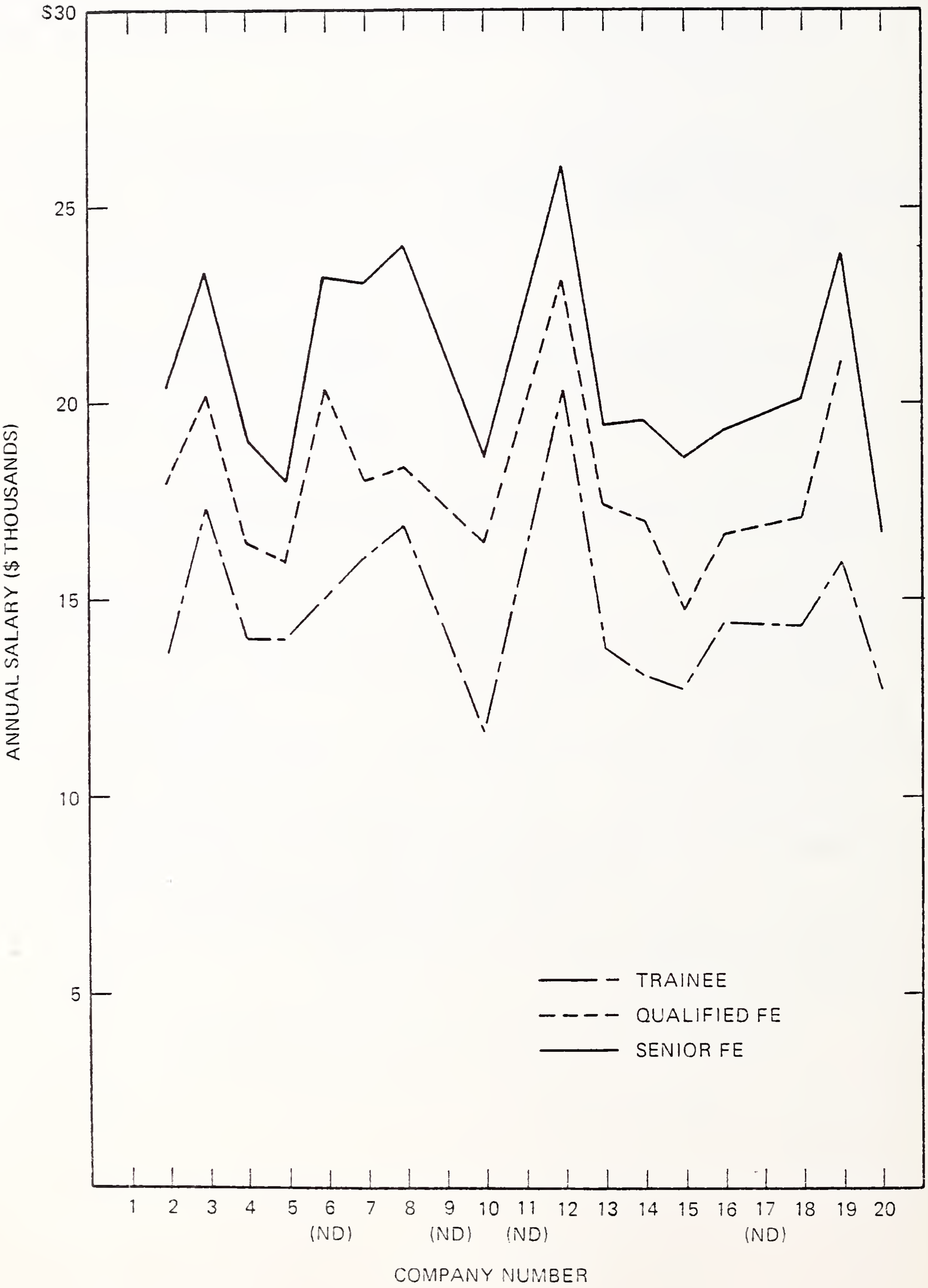
- Respondent vendors reported increases in salary ranges from 6% to 15% in 1980, with the average adjustment being 9.5%.

  - Reasons given for increases in salary ranges included:

    - "Competition."

EXHIBIT VII-4

COMPARISON OF AVERAGE SALARIES



ND = NO DATA

        - "Cost of living."
        - "Increasing FE responsibilities."
        - "Inflation."
        - "Supply and demand."
    - Reasons cited by vendors for individual increases in salaries included:
        - "Merit."
        - "Exceptional performance."
        - "Seniority."
        - "Promotion."
        - "Six-month reviews below mid-range, annual reviews above mid-range."
    - It is relevant that the inflation rate in 1979 was greater than the average salary increase reported by vendors; this can be a contributor to unrest among current field engineers.
- Five respondent vendors, all with West Coast headquarters, reported some form of incentive program for field engineers, including:
    - Commissions on service contracts and training courses sold.
    - Quarterly award to "FE of the Quarter," one for each region; one week combined business and pleasure meeting.
    - "Extra mile" awards for plus performers.

  - Percentage of contract revenues allocated as bonuses (two vendors).

- The absence of incentive programs at 15 respondent vendors often reflects unsuccessful incentive programs tried in the past.

- While commission-oriented incentive programs are not germane to the operating contractor's situation, some incentive program will be necessary in order to minimize turnover rates of skilled troubleshooting personnel.

- Some operating contractors have commented upon the negative effect affirmative action programs have had on their recruiting and training costs.

  - Vendors also report that recruiting costs have increased from 5% to 30% due to the need to meet affirmative action requirements.

  - One vendor reported an increase of 30% in training costs to meet the guidelines.

  - ARRCOM should recognize the potential extra expense burden and allocate funds accordingly.

B. TRAINING

- Most of the skilled people in the process control field have been trained by the vendors.

  - This is especially true of service personnel who may have received their initial electronics training in school but received detailed technical training by the systems vendor for whom they work, or by the vendor of the system used by the company for whom they work.

- Training techniques, personnel trends, and the coming shortage of personnel have been discussed in Chapter III.
  - A list of companies providing training services, including simulators, can be found in the Appendix C listing of professional services companies.

- User personnel, trained by the systems vendor, maintain and upgrade their skills as they work with the system on a daily basis.
  - Vendor personnel also maintain their system knowledge by working with the products constantly.

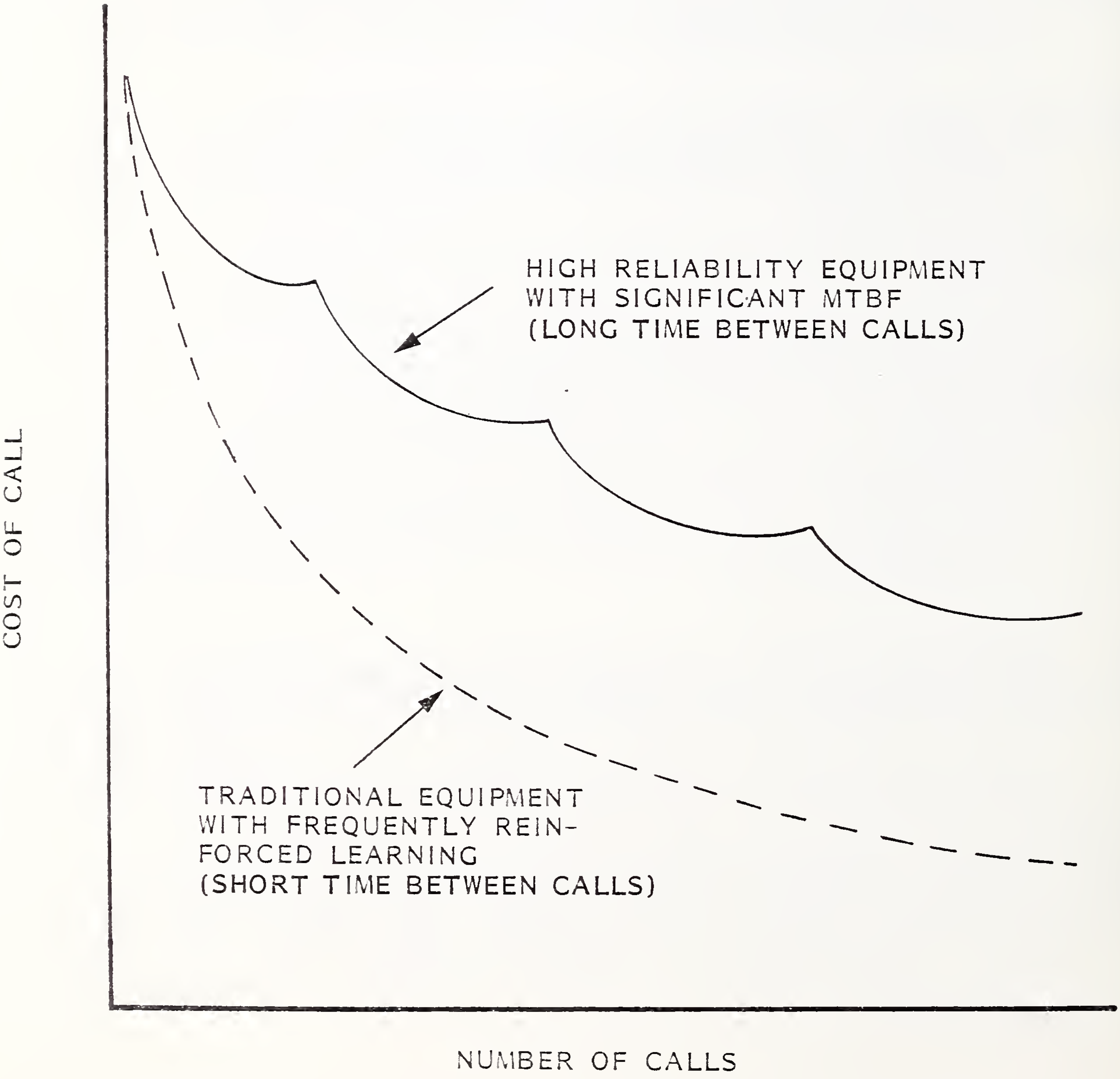
- As equipment becomes more reliable and fewer service calls are made, detailed knowledge of the systems is lost and must be regained each time service is required.
  - This problem is aggravated at the ammunition plants by long, dormant periods that may exist between reactivations.
  - Systems maintenance personnel at some ammunition plants claimed that being away from the system for six months required them to make extensive reviews of system material before they could confidently effect reactivation.

- Exhibit VII-5 conceptually shows the effect of elapsed time between calls on learning retention. In the dormancy situation, with long periods between service calls, the effect is greatly intensified. In other words, the "scallops" will be more pronounced as the average time between service calls increases.

- In order to minimize this effect, one or more of the new diagnostic and maintenance procedures must be employed. These include systems support centers, remote diagnostics, user self-maintenance, and, possibly, depot maintenance.

EXHIBIT VII-5

EFFECT OF ELAPSED TIME BETWEEN CALLS ON RETENTION OF LEARNING



GRAPH IS CONCEPTUAL TO DRAMATIZE THE EFFORT OF LEARNING EXTINCTION AS ELAPSED TIME BETWEEN CALLS INCREASES.

- Training that is wholly dependent upon the system vendor is at the mercy of the vendor's business decisions and, therefore, is not in the long-term best interests of any mobilization effort.

    - Vendor independent training capabilities can be achieved through the use of outside training companies or through the operating contractors' training facilities.

    - Training by lecture alone is not the best method. If the training material is presented via lecture alone, much detail can be lost with each succeeding lecture.

    - The objective training approaches are best, such as computer-based instruction or simulation.

C. PERSONNEL TRACKING

- Even if personnel have been away from the system for extensive periods of time, they can recall system details faster than new people can be trained.

- A personnel tracking system would provide a thread to everyone who has experience on a particular system.

    - System vendors can usually track people with particular skills as long as they remain employed with the vendor.

    - Operating contractors sometimes maintain information concerning the work histories of their employees and could "find" their people with EPCS experience as long as they remained employees.

- Most of the respondents felt that people experienced with a particular EPC system would cooperate with an attempt to keep track of skilled personnel in time of mobilization.

  - Such personnel, it was felt, would be willing to complete an annual questionnaire on their current location and status.

  - This kind of a skills inventory program must be undertaken by a group such as ARRCOM that has purview over all such systems.

  - Keeping track of all people who worked on a particular system at an ammunition plant would be of major interest. Of interest also are all people who have experience on a particular system regardless of the application.

D. PROFESSIONAL SERVICES COMPANIES

- Professional services companies that provide software services, consulting services, system design, etc. for the manufacturing industries are listed in Appendix C.

- These companies maintain skilled personnel in the various areas in which they specialize.

  - An analysis of these companies will uncover those that have skills in areas germane to the needs of the ammunition plants, and adroit courting of the companies will result in a relationship that will prove mutually beneficial in times of emergency.

  - In any geographic area, these companies form a skill pool that might be mobilized in times of emergency. Each ammunition plant with an EPC system should be aware of the professional services companies in the local areas and their particular expertise. Relationships should be built so that in emergencies, work can be performed with a minimum of red tape.

E. THIRD-PARTY MAINTENANCE COMPANIES

- The types of TPMs have been described previously.
    - A list of the major TPMs is given in Appendix D.

- The major national TPMs of either type would consider a contract to maintain the EPC systems at the ammunition plants and would maintain personnel trained in troubleshooting the installed systems.
    - The TPMs would consider only multiplant contracts and would also require a preliminary study contract to determine what needed to be accomplished at each plant.

- Many TPM companies will stock spares and also have reliable short-run production capabilities to make spares that are no longer available from the vendor.
    - Digital Equipment Corporation's field service organization has its own manufacturing facility and will produce spare parts for DEC systems that are no longer in production. DEC field service will only maintain DEC equipment.

- Some TPM companies such as GE and RCA would be interested in maintaining not only the electronic equipment but the entire automated production line.

- Third-party maintenance companies are a valuable resource that ARRCOM should cultivate.

VIII CONCLUSIONS

VIII CONCLUSIONS

- INPUT found no industry guidelines for long-term storage of electronic equipment. Thus, there are no established "rules" directly transferable to the ammunition plant situation.

  - Vendors exhibited little interest in the problem. Their thrust is toward reliability for systems that operate 24 hours a day, 365 days each year. The fallout from this goal will ease the long-term system maintainability problem.

  - Few users were found with storage requirements for electronic systems. One leasing company stored IBM 360 systems for two years in a heated warehouse. Each cabinet was kept in a large sealed plastic bag. A minimum number of problems occurred upon planned, deliberate reactivation. In short, systems can be stored.

  - Sufficient information is being gathered, however, under the ARRADCOM program so that explicit recommendations on storage conditions, reactivation procedures, and further testing, can be made with a high level of confidence.

- The effects of the strong trend in EPC system design toward distributed decision and control will be evidenced throughout the production line.

- Less redundant central site hardware will be necessary because the central site will become a management information collection point. Control will be effected in the field with less expensive hardware.

- The less expensive, versatile, programmable field controllers will provide a type of standardization that will in turn mean fewer spares to stock and easy replacement, leading to reduced MTTR and negligible MTSF.

- Systems manufacturers have recognized the advantages of providing families of systems so that as needs change, the system can grow at minimal cost and minimal downtime.

  - Compatible systems also allow for the use of the same software, eliminating costly program conversions.

  - Software will become more standardized between vendors as a result of the increasing use of the DOD-backed language ADA to be used for real-time and process control systems.

  - The increasingly dense chips that are being manufactured now and are on the drawing boards will provide economic incentives to the vendors to minimize the number of different chips used and to maintain the compatibility of their systems for longer periods. Withdrawal of vendor support for a system will be a less likely event because the family life will be extended.

  - The ammunition plant "design to operation" cycle that INPUT has witnessed is so drawn out that half a system's life cycle has passed before the production line is functioning.

A. AMMUNITION PLANTS

- U.S. Army ammunition plants are significantly different from commercial EPCS controlled plants.
    - The EPC system at a commercial plant is designed for round-the-clock operation.
    - Automated process or production lines at ammunition plants are also designed for round-the-clock operation. However, automated ammunition plants should be designed to reflect their anticipated life-cycle mode which includes:
        - A full production mode.
        - A partial production mode.
        - A dormant period.
        - Several reactivation cycles.
        - Several layaway cycles.
    - This lifetime approach to the design of automated production lines will result in the use of a different set of evaluation criteria when selecting all elements of the process line.
- Overall plant layaway responsibility lies with the operating contractor's facilities engineering group, and the EPC system is only a small part of the total plant.
    - The attitudes expressed by the facilities engineering people reflected the importance of the one production line to the entire plant.

  - Frequently no one person seemed to have special layaway responsibility for the EPC system. It was one of many items of concern and since little was known about the EPCs' layaway requirements, no special attention is given to the system.

  - The most interested operating contractor personnel, as far as EPCS layaway was concerned, were those people responsible for the system and funded to explore the problems of layaway. Those plants that had EPC systems under construction or in prove-out were less interested than those whose system was currently dormant.

- From the limited number of interviews done at the plants and perhaps because primarily operating contractor personnel were interviewed, factory automation programs seemed to lack a long-term coordinated planning effort and/or group.

  - This is evidenced by several factors:

    - The multiplicity of contractors involved in each individual system design.

    - The diversity of systems installed.

    - The lack of any sort of standardization that might alleviate the two major long-term problems of spare parts and trained personnel.

    - The lack of information, though it may exist, of system lifetime cost considerations. Only initial procurement, construction and installation costs seem to be considered at the contract award time.

- A negative undertone on the part of the operating contractors was detected by INPUT. This was not true in all cases, but it occurred enough times to cause concern.

  - This attitude seemed similar to one found in the commercial data processing world when the system was imposed upon a group without the group's full and/or sufficient participation in the system selection, design, etc. Under such conditions, it is very difficult to prove the system beneficial to the overall effort.

- INPUT found some, but little, evidence of in plant reliability programs in place and none that provided feedback to ARRCOM. Fortunately, the ARRADCOM MMT program is addressing this specific problem.

  - Failure reporting systems varied from plant to plant. Some were more organized than others, few accumulated information over time and organized the data for management, and even fewer claimed that management acted on the data presented or even knew of its existence. None indicated that ARRCOM would ever be notified in any formalized fashion of failure trends. This is being addressed, as discussed before, in the MMT program.

- No spare parts management system has been organized for these EPC systems, and the operating contractors have few guidelines of their own.

  - Spare parts have usually been stored in a reasonable manner for the short term, but this is because it is easier to leave them in their original packaging, and it is more convenient to keep the parts near the computer; therefore the parts are in a controlled environment. This has occurred on an ad hoc basis in the absence of any set of proper procedures.

  - Spares do not have the status in the Army's procurement scheme that INPUT feels they should have due to their critical role.

  - Spare parts requirements are not considered during the initial procurement cycle but are only included in operating funds.

  - No funds have been allocated for the testing of spares or for test equipment to do so.

- The retention of trained personnel, the training of new employees, and the retraining of skilled people is a major problem for the operating contractors and, therefore, for the U.S. Army.

  - Vendor-supplied training is sufficient initially, but this training is lost when the system is dormant.

  - The reactivation of the system periodically could provide a reasonable training activity. However, regulations prohibit the use of reactivation funds for training purposes.

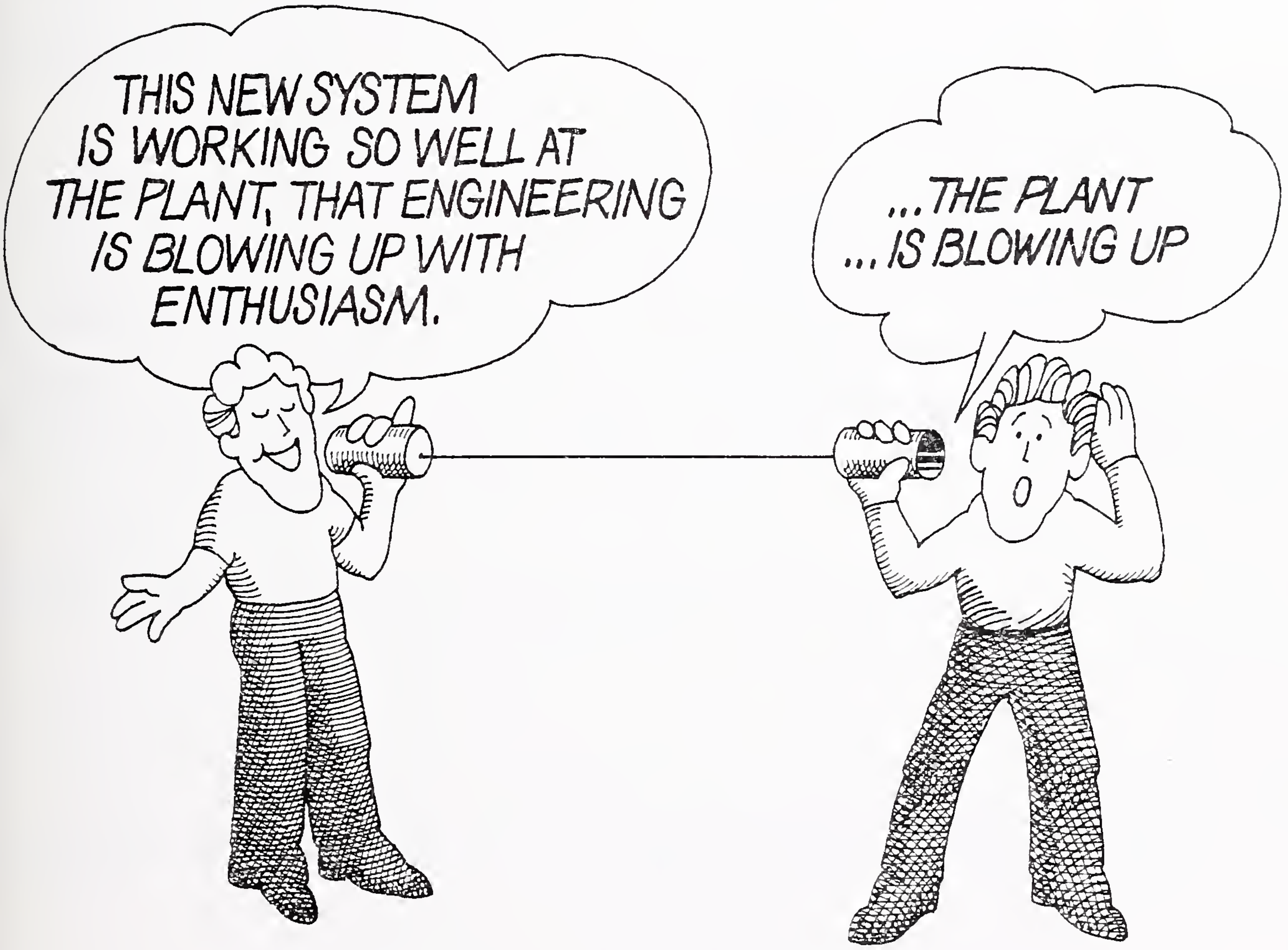
  - As systems become more reliable and as the military munitions industry practices "good" layaway techniques, the reactivations will go increasingly smoothly and there will be less and less opportunity to troubleshoot the system at that time.

  - Operating ammunition plants and plants that have EPC systems under construction, in prove-out, etc. do keep skilled engineering and maintenance personnel. Once the plant or EPCS is laid away, these people drift away to more challenging positions. Their skills are lost to the U.S. Army. There is no formal ARRCOM-operating contractor system in place which tracks these individuals from year to year and place to place.

- The multiplicity of contractors and the resulting dilution of responsibility at any one EPCS site has frequently led to a breakdown in communications, typified in Exhibit VIII-1, and sometimes the delivery of products, especially software, that were not suitable to be used as produced.

EXHIBIT VIII-1

COMMUNICATIONS - A KEY FACTOR


THIS NEW SYSTEM IS WORKING SO WELL AT THE PLANT, THAT ENGINEERING IS BLOWING UP WITH ENTHUSIASM.
...THE PLANT ...IS BLOWING UP

  - As a result, the design, construction, installation, testing, and operating cycles become drawn out over long periods of time (almost eight years in some cases) leading to a frustrated, demoralized operating group.

B. VENDORS

- Vendors understood the Army's problem, claimed a willingness to cooperate but were unwilling to second-source in-house designed components and were cagey about releasing documentation on in-house designed components even after they become obsolete.

  - This is due to existing patents and product protection.

- The increasing use of in-house designed components gives the vendor greater control over the system's life and, according to the vendors, will increase reliability but could have both a positive and negative effect on the Army's needs.

  - When the vendor passes on documentation, it will be more accurate and in greater depth than was previously available.

  - Second sources for components will be more difficult to find.

- Mil-spec components are not used in off-the-shelf equipment because the vendors must remain price competitive.

  - Some vendors are burning-in their components to the mil-spec standard.

  - Less reliable components such as plastic encapsulated chips and UV alterable proms are being either phased out or not used in critical portions of the systems.

C. USERS

- Users making a major investment in an automated plant or in a portion of the plant tend to protect that investment by:

  - Using a single overall contractor in the design and installation of the plant.

  - Fully participatng as the owner/operator in all aspects of the design through operation cycle.

  - Paying top dollars to the system vendor to accept full responsibility for the maintenance of the system. This includes stocking spares, keeping trained maintenance personnel available at all times, frequently on-site, and usually a contractual commitment to some uptime performance measure.

- It appears to INPUT that users of electronic process control systems have little inclination for doing maintenance work on their own or of using depots, etc.

  - At this point, users pay for on-site vendor maintenance and they get what they pay for.

  - The process control industry doesn't seem ready to follow the maintenance trends of the computer industry in general. The vendors will force the users into accepting some of the trends as costs increase and skilled personnel become increasingly rare.

- Users showed a greater interest in the layaway problem than the vendors, but the users had very little actual experience in this area.

  - Several are very interested in this study.

  - Just as vendors recommend leaving the system "on" in an idling mode for lack of better information, users also have left systems "on" out of fear of the unknown.

  - Two plants are being used as test sites under the MMT program with results to be applied to other Army facilities.

- After the initial burn-in period, users found system uptime in the over 98% range and in some cases close to 99.9%.

  - Preventive maintenance time is primarily used for work on the electromechanical portions of the system.

  - Those users who stocked their own spare parts followed the vendor's recommendation for their particular configuration and modified this practice based upon their own in-plant experience.

- Training is not a major problem at user sites. Vendors provide the initial training and daily interaction with the system provides the refresher course.

- Users generally do plan to replace systems when they become obsolete which requires careful, detailed planning and excellent communication between vendor and user personnel at all levels.

IX RECOMMENDATIONS

IX RECOMMENDATIONS

A. GENERAL

- As discussed in Chapter VIII, the conclusions section of this report, INPUT found that a large number of Army departments, contractors and subcontractors are involved in the specification, design, installation, and operation and maintenance of automated production lines. Between these elements, communication is generally weak, creating some confusion about responsibilities and commitments. Further, coordination is sometimes poor and objectives and priorities are ill-defined with the result that contractors do not always perform in the best interests of the Army.

- Three recommendations which would address these problems are:

  - Minimize the number of Army units and contractors associated with the program.

  - Increase the Army's supervisory role.

  - Institute long-term planning with continuity as a primary objective.

- Some specifics of these three recommendations are delineated in the following paragraphs.

I. MINIMIZE THE NUMBER OF UNITS INVOLVED

- INPUT is fully aware of the DOD procurement practices that can lead to a proliferation of entities being involved in any given program. It seems, however, that rapid reactivation of a munitions production line is the overriding program objective.

- The stages encountered over the life cycle of a production line are:

  - Specification.

  - Design.

  - Construction/installation.

  - Prove-out/acceptance testing.

  - Operation.

  - Maintenance.

- In the best of all possible worlds, one organization would have complete responsibility for all stages.

- Exhibit IX-1 shows a series of alternative "responsibility scenarios" going from best to worst case, as evaluated by INPUT.

  - In the best case, recognized as unlikely, ARRCOM could run the whole show.

  - In the worst case, a different organization has responsibility for each stage. The worst case scenario closely resembles the situation for many of the automated production lines in existence now.

EXHIBIT IX-1

ARRCOM AND CONTRACTOR RESPONSIBILITIES ALTERNATIVE SCENARIOS

	BEST ←		SCENARIOS		→ WORST
STAGE	1	2	3	4	5
SPECIFICATION	ARRCOM	ARRCOM	ARRCOM	ARRCOM	ARRCOM
DESIGN	ARRCOM	CONTRACTOR A	CORPS OF ENGINEERS	CONTRACTOR A	CONTRACTOR A
CONSTRUCTION	ARRCOM	CONTRACTOR A	CORPS OF ENGINEERS	CORPS OF ENGINEERS	CORPS OF ENGINEERS
PROVE-OUT	ARRCOM	ARRCOM	ARRCOM	CONTRACTOR A	CONTRACTOR B
OPERATION	ARRCOM	CONTRACTOR A	CONTRACTOR A	CONTRACTOR A	CONTRACTOR C
MAINTENANCE	ARRCOM	CONTRACTOR A	CONTRACTOR A	CONTRACTORS (MANY)	CONTRACTORS (MANY)

2. INCREASE THE ARMY'S SUPERVISORY ROLE

- Assuming that the Army cannot achieve the best case scenario, INPUT believes it is imperative that ARRCOM continue and be increasingly active in supervising all activities at each stage.
  - Constant monitoring and supervision can result in long-term continuity.
  - The longevity in grade of civil service personnel employed by the Army is likely to be better than that of contractor or military personnel.
  - Potential problems or departures from objectives can be spotted early so that anticipatory corrective actions can be taken in a timely manner.

3. INSTITUTE LONG-TERM PLANNING

- An automated production line needs to be planned, evaluated and considered in the context of its requirements over the lifetime of the line - typically 20 years.
  - INPUT perceives that the implementation of a line is seen as a one-shot task and that long-term implications are minimized.
  - The MMT 4322 program is addressing this situation.
- When seen in a long-term context, those parameters that are subject to change over a 20-year period will be identified. Once identified, contingency and action plans can be developed that define what should happen in the event of a change.
- Some items that can be better dealt with as a result of thorough long-term planning are:

- Costs - For example, when costs are projected over a 20-year life cycle, tradeoffs between initial expense and operating expense can be better analyzed.

- Personnel - For example, training requirements can be better defined if the frequency of personnel shifts is anticipated.

- States of readiness - For example, readiness requirements may change as a result of the global political situation. Planning for these fluctuations may dictate different approaches to construction, operation and maintenance.

- New technology - For example, should a production line be designed at the outset to accommodate new technology that may not be expected for ten years?

- In summary, INPUT recommends that a readiness function be identified and centralized within ARRCOM to focus on all new, existing, and planned EPC systems at the ammunition plants. This single group would have to be at a very high management level. The center would:

  - Establish standards for the design, procurement, installation, operation, sparing, layaway, reactivation and replacement of EPC systems.

  - Develop a long-term (20 years) plan for the acquisition of EPC systems.

  - Delegate responsibility to the operating contractors for appropriate portions of the total effort.

  - Assist the ammunition plants in planning, designing and procuring EPC systems.

  - Independently review and evaluate the operating contractor's EPC systems development plans, designs and projects.

- Establish a documentation center as assessed in MMT 4322, retaining all the documentation on all the systems and keep the documents updated.

- Establish a spare parts inventory management system that would keep track of the use and location of spares and issue guidelines for their storage.

- Establish a personnel management tracking system to maintain contact for at least a five-year period with people skilled in the use and maintenance of the installed EPC systems.

- Retain responsibility for all EPC systems' prove-out and acceptance.

- Be staffed with computer-skilled personnel, as well as factory automation and process control experts.

- Create a vendor liaison office to deal with suppliers on an ARRCOM-wide basis, thereby achieving some leverage.

- Operate a testing program, such as MMT, aimed at resolving some of the layaway issues that are unique to the military and for which there is no industrial experience.

- Aim at developing a strong bond of cooperation between ARRCOM, ARRADCOM, and the operating contractors and also among the operating contractors themselves.

- Apply the guidelines of MMT 4322 which addresses these problems.

B. SYSTEM PROCUREMENT RECOMMENDATIONS

1. STANDARDIZE

- Automation equipment and software should be standardized across similar production lines and, whenever feasible, even across dissimilar lines.
  - This implies that the entire munitions production program be perceived as a single program, and not as a mixture of independent entities.
- Standardizing on equipment means:
  - More incentive to selected vendors to perform.
  - Fewer spares requirements because of parts interchangeability.
  - Fewer training programs.
  - Easier transfer of people.
  - Simpler reliability improvement programs since information need be gathered on fewer pieces of equipment.
- Standardizing on software means that, regardless of the equipment, the software interfaces all appear the same to the applications programmers.
  - ADA should be used if DOD formally adopts it.

2. SEEK VENDORS WHO CAN DEMONSTRATE LONG-TERM COMMITMENTS

- Only vendors of equipment and software who can demonstrate a long-term commitment to the products they would provide for the munitions production lines should be considered as viable bidders.

- Vendors should be required to present evidence of this commitment in their proposals. Some of the items that can be construed as evidence are:

  - Written commitment to provide spares over the projected lifetime of the product or designation of second sources who can make such a commitment.

  - Written commitment not to drop support when systems are upgraded or replaced.

  - Fail-safe provisions for turning over proprietary drawings, bills of materials, etc. in the event support is withdrawn at some future time.

  - Progressive maintenance policies, including programs for customer training and assistance with provision for distributing these programs to munitions plants in remote locations at reasonable costs.

  - Superior facilities for equipment and/or software diagnosis and repair including such things as remote diagnostics, easily accessible repair and spares depots, centralized fault/fix data bases, etc.

3. SPECIFY REQUIREMENTS

- INPUT believes that the long-range needs of the munitions production lines are not always translated into requirements specifications for system procurements at the component or subsystem level. In other words, the implications of long dormancy, fast reactivation, etc. over a 20-year span are not considered.

  - In future procurements, these requirements should be specified at a very detailed level, and subsystem or component bidders should be required to address these specifications.

- In relation to the twin problems of reliability and maintenance, the items that should be detailed in the specifications are:

  - Documentation - current and upgrades.

  - Support facilities - type and location.

  - Training - methods and frequency.

  - Maintenance procedures.

  - Spares - stocking levels.

  - Layaway - specifications and procedures.

  - Reactivation procedures.

- Layaway requirements should be included initially in every system procurement. Requests should be made to vendors to provide information on the effects of long-term storage on the equipment proposed. Pressure to force vendors to respond can be accomplished in two ways:

  - Seek the cooperation of other military and/or federal agencies who have similar requirements in jointly making known that the vendors who will undertake such accelerated life testing will gain rating points in any competitive bidding situation.

    . Make this a part of the scope when purchasing.

  - Require vendors to respond to a section in each EPC system bid solicitation that requests information on the ease of layaway and the effects of dormancy. Make it known that vendors' responses will be an important part of the vendor responsiveness evaluation scheme.

    - INPUT recognizes that this is difficult but believes that it is important.

- Each EPCS bid solicitation should contain a section on lifetime costs, and the estimated lifetime costs should be made a significant factor in choosing a vendor or evaluating the responses to the solicitation.

  - Each solicitation should require the vendors to estimate the lifetime costs of the proposal based upon a series of different possible events that might occur, such as those shown in Exhibit IX-2. The solicitation would have to include a list of cost assumptions such as power, labor, etc. and would have to ask the vendor to supply cost breakdowns including spare parts, preventive maintenance, etc. If several vendors make a joint bid, then each should respond fully for the subsystem bid.

C. MAINTENANCE PROCUREMENT RECOMMENDATIONS

1. SPARES

- Access to an adequate supply of spares over the projected system lifetime must be ensured.

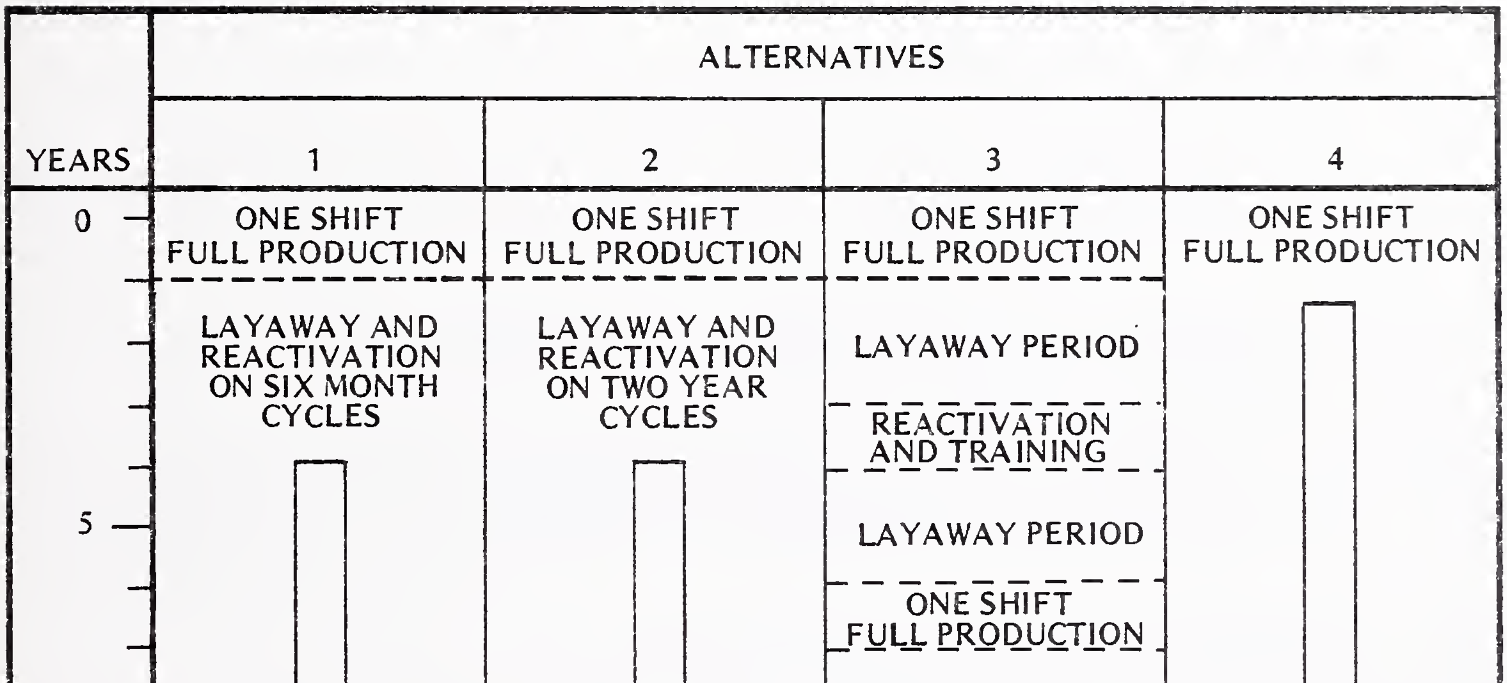
  - Consideration should be given to buying spares initially or at least allocating the funding for future spares procurement along with the initial procurement contract.

  - Provision of funds should also be made for purchasing test equipment to test incoming spare parts on a sample basis.

- A backup program (should manufacturers go out of business or otherwise drop support) for spares replacement must be instituted.

EXHIBIT IX-2

SUGGESTED EPC SYSTEM USAGE ALTERNATIVES


YEARS
ALTERNATIVES
1
2
3
4
0
5
10
15
20
ONE SHIFT FULL PRODUCTION
LAYAWAY AND REACTIVATION ON SIX MONTH CYCLES
ONE SHIFT FULL PRODUCTION
LAYAWAY AND REACTIVATION ON TWO YEAR CYCLES
ONE SHIFT FULL PRODUCTION
LAYAWAY PERIOD
REACTIVATION AND TRAINING
LAYAWAY PERIOD
ONE SHIFT FULL PRODUCTION
THREE SHIFTS FULL PRODUCTION
ONE SHIFT HALF PRODUCTION
LAYAWAY PERIOD
REACTIVATION AND TRAINING
LAYAWAY PERIOD
ONE SHIFT FULL PRODUCTION

- A program for testing spares is needed. (At one user facility, INPUT was told that 50% of spares were found to be defective.)
    - Test specifications must be established. In most cases, the manufacturers' specifications will be adequate.
- If standardization of systems can be achieved over a broad enough base, ARRCOM should consider purchasing a backup system that could be moved into any site to replace a down system that could not be repaired within reactivation time requirements.
    - This system should be kept in a controlled environment off-site from any munitions plants.
    - The system should be kept in top working order at all times.
    - Fault/fix information from this backup system should also feed into the centralized data base as part of the reliability improvement program.
- Guidelines in MMT 4322 address this issue.

2. PERSONNEL TRAINING

- A system for keeping track of all personnel skilled at diagnosing or repairing equipment, software or systems should be established after they have retired or left the employ of the Army or contractors. The government could then attempt to call on these people in case of national emergency.
    - Such programs exist within some operating contractor's organizations and within some vendor organizations, but a broader program uniformly administered is necessary.

3. TRAINING AND RETRAINING

- Provision should be made for an ongoing formal training/retraining program.

  - Newer techniques, such as video or computer-based instruction should be considered, especially for retraining.

- Reactivation periods should be used as on-site training and retraining laboratories.

  - Army regulations should be modified so that this process is legal.

4. ESCALATION PROCEDURES

- Suitable escalation procedures for both prime and all subcontractors should be clearly stipulated to ensure all possible resources are brought to bear on difficult maintenance problems, and that contractor/subcontractor responsibilities are clearly delineated. This should eliminate the common "finger-pointing" syndrome.

  - The optimum repair level analysis refers to this, according to ARRADCOM.

5. RELIABILITY IMPROVEMENT PROGRAM

- An ongoing reliability improvement program should be established. The program, at a minimum, should consist of:

  - A reporting system wherein each fault and fix is reported centrally.

  - A procedure for analyzing the resulting data.

  - A system to provide feedback to all parties who can effect improvements.

- ARRCOM should consider using the facilities of one of the computer system vendors since most are well set up to handle this kind of program.

  - If this is not feasible, ARRCOM should establish and operate its own system. The Defect and Failure Reporting form, discussed earlier, should address this issue.

6. CHOICE OF MAINTENANCE PROVIDER

- INPUT's recommendation that ARRCOM-ARRADCOM handle its own maintenance notwithstanding, there are several choices of maintenance provider.

  - The plant operating contractor.

  - The equipment manufacturer(s).

  - A third-party maintenance (TPM) vendor.

- The best of these alternatives is the plant operating contractor because a single entity can be held accountable for the functioning of the line or plant.

- The second choice is the process control system equipment provider, since it is closest to the equipment and can presumably draw upon superior talent.

  - Because of the remote geographic distribution of the equipment, vendors may not be interested in assuming prime responsibility.

- In the event the preferred choices are not viable, TPM vendors should be considered.

  - INPUT recommends the "facilities TPM" type of vendor.

    - These are usually divisions of very large companies which presumably would offer a better chance for long-term viability because they have superior financial, personnel, and technical resources.

  - It is doubtful that a facilities TPM vendor would take a small contract. Therefore, ARRCOM should consider awarding large contracts that either cover multiple plants or cover more equipment than just the process control system in a single plant.

    - An example of the latter would be to include such electronic systems as fire control, closed circuit TV, telephones, etc.

- In any case, regardless of the type of maintenance vendor selected, contracts should provide strong financial performance incentives in order to help ensure that performance objectives are achieved.

- Contractor personnel interviewed by INPUT generally stated that they saw automated control systems as such a small piece of the overall plant that they gave it relatively low priority.

  - ARRCOM should require that one person with the operating contractor's facilities engineering group (or another group that has layaway responsibility) have sole responsibility for EPCS layaway. This person should have adequate funds available to do a complete job. Some computer orientation, especially a maintenance background, would be an essential requirement for this position.

7. LINES OF COMMUNICATION

- The maintenance contract should clearly stipulate how the maintenance vendor should communicate with equipment manufacturers, other contractors, and the Army.

- In particular, documentation flow should be spelled out as part of a plan that delineates responsibilities, reporting systems, and lines of authority.

D. LAYAWAY AND REACTIVATION RECOMMENDATIONS

I. LAYAWAY RECOMMENDATIONS

- INPUT recommends that the layaway/reactivation cycle be extended from the successful six-month period to the longest period found among the interviewees - two years.
  - This two-year cycle should be considered an experiment and should be properly monitored. At least a six-year test should be considered.
  - The test should be carried out in three parts:
    - Equipment should be stored in a controlled environment with a temperature of 70° and humidity at 40%, just as the Joliet AAP equipment was stored during the three-year storage with six-month test intervals.
    - Equipment should be stored in a heated area and an appropriately sized capsule be used in the equipment enclosure as an anticorrosion agent. The cabinet should be covered with ordinary plastic to keep them dust free.
    - Equipment should be stored in a heated area and enclosed in sealed plastic bags. These bags should be ziplocked if possible rather than heat-sealed because heat-sealing frequently gives off gases which could harm the metallic surfaces. The plastic bags

should be tested to see if harmful vapor results from the heat-sealing process.

- Caution - ZERUST® capsules, which may be used, exude a vapor that protectively coats the metal surfaces. INPUT has seen no tests that show that the vapor does or does not have to be removed before the equipment, using the extremely low current levels found in modern computers, can be activated. If the vapor must be removed before the components will work properly, then the ZERUST® products should not be considered for the application. INPUT urges that complete tests be carried out before this product is used for the storage of modern electronic equipment. General effectiveness test results can be found in Appendix E.

- Valves, actuators and sensors can remain on the line if tests show that they can survive. If the pipes, vessels, cabinets, and/or machinery in which they function can be closed off, then capsules or bags as appropriate should be used.

    - For long-term storage, the best procedure is to disassemble the valves, actuators, sensors, etc., clean all parts thoroughly, and store in sealed bags.

- Paper products such as documentation, punched cards and paper tape should be stored in several places within the plants and at the technical center at ARRCOM-ARRADCOM.

    - Paper products should be kept in a more humid environment than electronic equipment.

        - Spare parts should not be stored in brown (Kraft) paper bags or in corrugated cardboard bins. Paper products are made with a sodium sulfate solution, and the sulphur will harm the parts if they are stored for long periods of time.

  - The parts should be stored in ziplocked plastic bags or in ZERUST® plastic bags if ZERUST® passes the current level test.

- A two-year or longer dormant period seriously affects retention of system knowledge by the operating contractor's skilled people.

  - INPUT recommends the adoption of a computer-based instructional program such as PLATO by Control Data Corporation or a simulator training program that will simulate a "hands on" training environment.

2. REACTIVATION RECOMMENDATIONS

- The basic procedure when reactivating a system after it has been dormant is to very carefully follow the vendor's procedure for startup as if the system is brand new.

  - It is imperative, therefore, that the operating contractor's personnel or whoever will have reactivation responsibility be present at the initial startup, document the procedure thoroughly, and obtain full documentation of the process from the vendor. This documentation must be kept up-to-date.

  - The MMT 4322 procedures will supplement this procedure and may be used during start-up.

- The packing, whether plastic bags or something else, must be undone carefully so as to minimize disturbing the dust accumulation.

  - If not covered and/or kept in a controlled environment, the parts must be vacuumed thoroughly and carefully, with special attention to electromechanical units such as disk drives and printers.

- A thorough visual inspection of all units, cabinets, subassemblies, boards, chips and other components must be undertaken. This was stressed as being an especially important procedure because many potential problems can thus be averted.

    - Boards, chips, etc. should not be unseated as a matter of course. They should be reseated if they appear loose.

    - Cabling must be very carefully inspected and should be handled to test for brittleness.

        - Antioxidants from commonly used insulating materials evaporate over time (regardless of whether the equipment is in storage or not) leaving the insulation very brittle and subject to cracking. If this occurs the cables must be replaced.

        - Some insulating materials are less likely to become brittle. These should be specified in all contracts calling for long-term use of the cables, especially if dormant periods are anticipated.

    - The mechanical subassemblies of electromechanical equipment must be examined for grease deterioration. All equipment on the entire production line that requires grease for proper operation must be similarly inspected.

        - Studies should be undertaken to find or develop greases less subject to deterioration, and they should be specified in EPC system procurements.

- If the storage period is greater than two years, all gaskets, O-rings, seals, etc. should be discarded and replaced with new ones.

    - These are usually standard items and should be purchased fresh for each reactivation.

    - Recalibration must also be done on all devices that have been disassembled and require calibration.

- All equipment should be brought up slowly in 20% increments, keeping it a few hours at each level.

    - The equipment is maintained under "no load" conditions for 24 hours.

    - Special attention must be paid to the slow reforming of the capacitors and to all power supplies, as done successfully at JAAP and VAAP.

    - All special cautions and other instructions from the vendors should be followed unless experience shows that they may not be necessary. However, certain warranties might be voided by not following the vendor's instructions carefully.

- All loops should be tested and brought up individually before testing for interaction between loops.

- A precise failure reporting system should be in place before the reactivation starts, as done under the ARRADCOM MMT 4322 program.

    - Not only must the fault be well documented, but the symptom and troubleshooting procedures must also be thoroughly described as part of a good management feedback system.

E. EXISTING FACILITIES

- Existing facilities should be brought up to the level of new procurements if all the recommendations of this report are followed.

  - A person within each operating contractor's organization should be assigned responsibility for layaway, and that function should be adequately funded.

  - A spare parts management system should be instituted with strict adherence to dating, storing and testing procedures.

  - A documentation hierarchy should be developed, and the documents collected and organized along with thorough procedures for updating.

  - Vendor-independent training programs should be developed.

- During construction and installation of the system, since the cycle is so drawn out, new equipment should be treated as if it were in layaway.

- The MMT 4322 reportedly addresses a number of these needs.

F. PCP-88 SYSTEMS RECOMMENDATIONS

- The following recommendations pertain to the PCP-88 systems at JAAP, VAAP and RAAP only. They have been singled out because the vendor of these systems, the Foxboro Company, Inc., has announced the withdrawal of support as of December 31, 1982.

- Withdrawal of support by Foxboro means that:

  - Spare parts will no longer be produced and, as existing supplies are bought up, spares will become increasingly rare. Existing PCP-88 systems may serve as a source of spare parts.

  - Documentation will not be updated and as supplies run out will not be available. Hopefully, large system changes will not be made and existing documentation will be useful.

  - Formal training courses may not be given and training material will not be available.

  - Maintenance services will not be guaranteed on a formal basis from Foxboro.

  - The ammunition plants will be largely "on their own" either singly or jointly with respect to the automated lines using the PCP-88 control system.

- All the preceding recommendations apply to these systems. The following recommendations, while similar to some of the preceding, should be instituted more rapidly and more thoroughly than may occur with new systems.

- INPUT recommends that the PCP-88 systems be kept and maintained as long as possible and that everything necessary be done to foster this effort.

  - The PCP-88 system is a proven system with uptimes in commercial experience of greater than 98%.

  - The PCP-88 system has successfully survived layaway and reactivation periods and has shown no indication of not being able to continue further with such a program.

  - The spare parts, personnel, documentation problems, etc. caused by Foxboro's dropping of support for the PCP-88 can be greatly alleviated by prompt action on the programs outlined in this report.

- INPUT recommends that a single office or group at ARRCOM-ARRADCOM be created and charged with the full responsibility of implementing all programs necessary to maintain the three PCP-88 systems. This must be done whether or not a systems development center is established at ARRCOM-ARRADCOM. These programs should include:

- A documentation program with all hardware and software documents stored in a central location under conditions designed to best preserve and safeguard them.
    - This documentation must be obtained from Foxboro and all subcontractors as necessary. Proprietary documentation should be releasable once the product is no longer manufactured.
    - Detailed vendor lists are a necessary part of the program.
- A spare parts program that would maintain a complete set of spares and emphasize those spares that experience difficulties or high failure rates and which studies show to be most vulnerable.
    - Testing, dating, cycling, repairing and proper storage are basic elements of the program.
    - Also this program must locate and maintain a list of companies that will duplicate any component in short-run quantities.
    - Maintenance of an up-to-date second source file is a major activity of this office.
- A vendor-independent training capability must be established and maintained.
    - Elements of this capability exist currently. This should be expanded and updated if necessary. Training materials should be purchased from Foxboro and all other pertinent subcontractors.

  - Additional programs as deemed necessary to maximize the life of the systems and, therefore, the Army's return on its investment.

    - An important program must be undertaken to determine if the PCP-88 system can effectively control multiple TNT lines simultaneously. The software must be debugged and the effect of the multi-line interaction on production capability must be estimated.

  - The operating contractors must be represented in this group.

- INPUT recommends that large national third-party maintenance companies be offered the opportunity to maintain the PCP-88 system.

  - These companies should be asked to guarantee:

    - To keep a cadre of trained personnel.

    - To procure spare parts as needed through purchase or manufacture.

    - To reactivate the system periodically as determined by the appropriate Army commands.

- INPUT suggests that if the U.S. Army is going to proceed with its modernization program at the ammunition plants in general, and at VAAP and JAAP in particular, then the Army should:

  - Automate the other lines using the latest hardware, software and process knowledge.

  - When these lines are proved-out then replicate these new systems on the PCP-88 lines.

- Adopt systems that have been proved-out on other CIL continuous process lines to avoid the costly and disruptive conversion process.

- Consider separately the system at RAAP, since at this time it is a single system for a unique process.

- If the U.S. Army chooses not to automate additional CIL continuous process lines, then at some point conversion will be required. ARRCOM-ARRADCOM should consider adopting the Navy's project management and control system for use in estimating and managing such conversion.

APPENDIX A: SOURCES AND BIBLIOGRAPHY

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APPENDIX B: DEFINITIONS

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- AUTOMATED REMOTE DIAGNOSTICS - A remote diagnostic system that interfaces with an automated analysis routine at the remote assistance center.

- BRING-UP DIAGNOSTICS - Specialized diagnostics designed during the equipment development phase to verify the functional integrity of various stages of design. Usually incorporated into the field diagnostic package as verification routines.

- CLOSED LOOP (feedback loop) - A signal path which includes a forward path, a feedback path and a summing point, and forms a closed circuit.

- COMPUTING INSTRUMENT - A device in which the output is related to the input or inputs by a mathematical function such as addition, averaging, division, integration, lead/lag, signal limiting, squaring, square root extraction, subtraction, etc.

- CONTROL ROOM - A location with heat and/or cooling facilities. Conditions are maintained within specified limits. Provisions for automatically maintaining constant temperature and humidity may or may not be provided. Note: Control room areas are commonly provided for operation of those parts of a control system for which operator surveillance on a continuing basis is required.

- CONTROL SYSTEM - A system in which deliberate guidance or manipulation is used to achieve a prescribed value of a variable.

- CONTROL VALVE - A final controlling element through which a fluid passes, which adjusts the size of flow passage as directed by a signal from a controller to modify the rate of flow of the fluid.

- CONTROLLER - A device which operates automatically to regulate a controlled variable.

- DIAGNOSTIC AIDS - Various devices and resources that assist in the effort to diagnose equipment problems. Some examples are: diagnostics, remote diagnostics, error logs (manual), on-board statistical error logs, documentation, special test equipment, FE panels, etc.

- DIAGNOSTICS - Programmed routines used to verify the functional integrity of computer equipment, to force failures, report on failure patterns, and to isolate faults through fault-locating techniques.

- DISTRIBUTED PROCESSING - The deployment of programmable intelligence to the site where the particular processing function is performed. Computers, controllers and devices are interconnected through communications lines adapted to individual user needs.

- DISTRIBUTOR - Purchases the programmable controllers, sensors, actuators, etc. on an OEM basis from the manufacturer and markets them to the end user.

- END USER - May buy a system from the hardware supplier(s) and do his own programming, interfacing, and installation. Alternatively, may buy a turnkey system from a systems house or hardware integrator.

- ENGINEERING CHANGE NOTICE - Notice of improvements or corrections in a product after it has been released to production or has been installed at the user's site.

- ENGINEERING CHANGE ORDER (ECO) - Instructions including bill of material and parts required to effect the engineering change.

- FLTs - A specialized diagnostic package designed to isolate fault in a failing computer device. The abbreviation of "Fault-Locating Tests."

- FIELD ENGINEER (FE) - An individual who responds to a user's call for service and repairs a device or system. FE is used interchangeably with customer engineer, serviceperson, maintenance person, etc.

- FLOWMETER - A device that measures the rate of flow or quantity of a moving fluid in an open or closed conduit. It usually consists of both a primary and a secondary device. Note: It is acceptable in practice to further identify the flowmeter by its applied theory; as differential pressure, velocity, area, force, etc. or by its applied technology as orifice, turbine, vortex, ultrasonic, etc. Examples include turbine flowmeter, magnetic flowmeter, fluidic pressure flowmeter, etc.

- HARDWARE - Physical equipment directly involved in performing industrial process measuring and controlling functions.

- INSTRUMENTATION - A collection of instruments or their application for the purpose of observation, measurement or control.

- MEAN TIME BETWEEN FAILURES (MTBF) - The average of a series of measured elapsed time intervals between reported failures on a device or system.

- MEAN TIME TO REPAIR - The average of a series of measured elapsed time intervals between a field engineer's arrival at the user's site and the repaired device's return to full operation.

- MEAN TIME TO RESPOND - The average of a series of measured elapsed time intervals between a user's service call and a field engineer's arrival at the user's location.

- MEAN TIME TO SYSTEM FAILURE - The average of a series of measured elapsed time intervals between instances of total system failure.

- MODULE - An assembly of interconnected components which constitutes an identifiable device, instrument, or piece of equipment. A module can be disconnected, removed as a unit, and replaced with a spare. It has definable performance characteristics which permit it to be tested as a unit. Note: A module could be a card or other subassembly of a larger device, provided it meets the requirements of this definition.

- OPEN LOOP - A signal path without feedback.

- PERIPHERALS - Include all input, output, and storage devices, other than main memory, which are locally connected to the main processor and are not generally included in other categories, such as terminals, sensors, actuators, etc.

- PROCESS CONTROL - The regulation or manipulation of variables influencing the conduct of a process in such a way as to obtain a product of desired quality and quantity in an efficient manner.

- PROCESS MEASUREMENT - The acquisition of information that establishes the magnitude of process quantities.

- PROGRAMMABLE CONTROLLER - A controller which automatically holds or changes a set point to follow a prescribed program for a process.

- QUALITY ASSURANCE DIAGNOSTICS - Combinations of manual tests and algorithms run under variable conditions of environmental stress to ensure that equipment runs properly at and beyond specified condition limits. Seldom used by field engineers and only recommended in extreme cases within the user's environment.

- RELIABILITY - The probability that a device or system will perform its objective adequately, for the period of time specified, under the operating conditions specified.

- REMOTE DIAGNOSTICS (RD) - Diagnostics run by the vendor from a remote location without the intervention of the user's operator; diagnostics run by an on-site field engineer tied to a central support center, or by a user tied to a central support center. It can usually isolate a fault to the lowest exchangeable unit.

- SET POINT - An input variable which sets the desired value of the controlled variable. Note 1: The input variable may be manually set, automatically set, or programmed. Note 2: It is expressed in the same units as the controlled variable.

- SHARED TIME CONTROL - Control in which one controller divides its computation or control time among several control loops rather than by acting on all loops simultaneously.

- SUPERVISORY CONTROL - Control in which the control loops operate independently subject to intermittent corrective action; e.g., set point changes from an external source.

- SYSTEM SUPPORT CENTER (SSC) - A central technical support facility staffed by highly skilled field engineers and accessed over a national "hotline" number. A system support center is available to both users and field engineers for the analysis of problems in hardware, software or a combination of the two.

- USER SELF-MAINTENANCE (USM) - Some involvement by individual users in the installation, diagnosis and repair of their own installed equipment.

- WARM-UP PERIOD - The time required after energizing a device before its rated performance characteristics apply.

APPENDIX C: COMPUTER PROFESSIONAL SERVICES COMPANIES

APPENDIX C: COMPUTER PROFESSIONAL SERVICES COMPANIES

A. LIST I

- Revenues: More than $5,000,000.

- Over 50% of revenue obtained from software products and professional services.

- Over 30% of revenue obtained from the manufacturing sector of the economy.

  - Allen Services Corporation
    212 W. National Road
    Vandalia, OH 45377
    (513) 890-1200
    A. Allen, President

  - Applied Information Development (AID), Inc.
    823 Commerce Drive
    Oak Brook, IL 60521
    (312) 654-3030
    Lee Munder, President

  - Cincom Systems, Inc.
    2300 Montana Avenue
    Cincinnati, OH 45211
    (513) 662-2300
    Thomas M. Nies, President

- Cognа Systems Corporation
  222 North Dearborn
  Chicago, IL 60601
  (312) 431-6700
  J.M. Roe, President

- Cullinane Database Systems, Inc.
  400 Blue Hill Drive
  Westwood, MA 02090
  (617) 329-7700
  John J. Cullinane, President

- Information Science, Inc.
  95 Chestnut Ridge
  Montvale, NJ 07645
  (201) 391-1600
  Jack Hight, President

- Informatics, Inc.
  21031 Ventura Blvd.
  Woodland Hills, CA 91364
  (213) 887-9040
  Walter F. Bauer, Ph.D., President

- Logicon, Inc.
  21535 Hawthorne Blvd.
  Torrance, CA 90503
  (212) 540-9200
  John R. Woodhull, President

- Pansophic Systems, Inc.
  709 Enterprise Drive
  Oak Brook, IL 60521
  (312) 986-6000
  Joseph A. Piscopa, President

- Scientific Software Corporation
  633 17th Street
  Denver, CO 80202
  (303) 571-1111
  E.A. Breitenbach, Ph.D., President

- Software Ag of North America, Inc.
  11800 Sunrise Valley Drive
  Reston, VA 22091
  (703) 860-5050
  John Maguire, President

- Software International Corporation
  2 Elm Square
  Andover, MA 01810
  (617) 475-5040
  William G. Watson, President

- Structural Dynamics
  Research Corporation
  2000 Eastman Drive
  Milford, OH 45156
  (513) 576-2400
  Jason R. Lemon, President

B. LIST II

- Revenues: More than $5,000,000.

- Over 50% of revenue obtained from software products and professional services.

- Some revenue from the manufacturing sector.

- AGS Computers, Inc.
  1135 Spruce Drive
  Mountainside, NJ 07092
  (201) 654-4321
  Lawrence J. Schoenberg, President

- Advanced Computer Techniques Corporation
  437 Madison Avenue
  New York, NY 10022
  (212) 421-4688
  Charles P. Lecht, President/Chairman

- Analysts International Corporation
  7615 Metro Blvd.
  Minneapolis, MN 55435
  (612) 835-2330
  Frederick W. Lang, President

- Auxton Computer Enterprises
  1345 Avenue of the Americas
  New York, NY 10019
  (212) 489-7620
  John P. Croxton, President

- C.A.C.I., Inc.
  1815 Ft. Meyer Drive
  Arlington, VA 22209
  (703) 841-7800
  William W. Fair, Ph.D., President

- CGA Computer Associates, Inc.
  25 Commerce Drive
  Cranford, NJ 07016
  (201) 272-3900
  Bernard M. Goldsmith III, President

- Computer Company (The)
  1905 Westmoreland Street
  Richmond, VA 23230
  (804) 358-2171
  Walter R. T. Witschey, President

- Computeristics, Inc.
  Benson Road
  Middlebury, CT 06749
  (203) 573-2222
  James H. Chambers, President

- Computer Sciences Corporation
  650 North Sepulveda Blvd.
  El Segundo, CA 90245
  (213) 615-0311
  William R. Hoover, President

- Computer Task Group, Inc.
  800 Delaware Avenue
  Buffalo, NY 14209
  (716) 882-8000
  David N. Campbell, President

- Comtech Group International Ltd.
  5 Fairview Mall Drive
  Suite 380
  Willowdale, Ontario NM2J2
  (416) 492-1480
  Donald McPhail, President

- Consumer Systems Services Group, Inc.
  2107 Swift Drive
  Oakbrook, IL 60521
  (312) 325-2109
  Ray M. Dionisio, President

- Cutler Williams, Inc.
  2655 Villa Creek Drive
  Dallas, TX 75234
  (214) 243-3421
  George Enochs, President

- Cybernetics and Systems, Inc.
  6100 Dutchman's Lane
  Louisville, KY 40205
  (502) 459-8080
  Al Bailey, President

- DASD Corporation
  9045 N. Deerwood Drive
  Suite 301
  Milwaukee, WI 53209
  (414) 355-3405
  Martin R. Marshall, President

- Data Communications Corporation
  3000 Directors Row
  Memphis, TN 38131
  (901) 345-3544
  President, Chairman

- Galler Associates, Inc. (GAI)
  1815 North Fort Myer Drive
  Arlington, VA 22209
  (703) 525-9292
  Jerry Galler, President

- Intel Systems Corporation
  12575 Research Blvd.
  P.O. Box 9968
  Austin, TX 78766
  (512) 258-5171
  Kent Ochel, President

- Keane, Inc.
  210 Commercial Street
  Boston, MA 02109
  (617) 742-5210
  John F. Keane, President

- Litton-Mellonics
  1001 West Maude Avenue
  Sunnyvale, CA 94086
  (408) 245-0795
  Richard W. Baker, President

- Martin Marietta Data Systems
  300 East Joppa Road
  Baltimore, MD 21204
  (301) 321-5700
  Richard J. Walters, President

- Monchik-Weber Corporation
  111 John Street
  New York, NY 10038
  (212) 962-2400
  Stewart Monchik, President

- Payne Consultants, Inc.
  Time & Life Building
  Rockefeller Center
  New York, NY 10022
  (212) 581-5500
  Bruce Payne, President

- Project Software & Development, Inc.
  14 Story Street
  Cambridge, MA 02138
  (617) 661-1444
  Robert L. Daniels, President

- Rand Information Systems, Inc.
  98 Battery Street
  San Francisco, CA 94111
  (415) 392-2500
  E. Donald Shapiro, Chairman

- Security Mutual Casualty Data Services
  222 South Riverside Plaza
  Chicago, IL 60606
  (312) 621-4612
  Elwood D. Yeater, Vice President

- Spiridellis & Associates, Inc.
  133 Avenue of the Americas
  New York, NY 10036
  (212) 221-7270
  Nikolaous T. Spiridellis, President

- Systems and Programming Resources, Inc.
  1211 W. 22nd Street
  Suite 600
  Oakbrook, IL 60521
  (312) 654-4188

- Systems Architects, Inc.
  Thomas Patton Drive
  Randolph, MA 02368
  (617) 961-4840
  George Pan, President

- Systems Engineering Computer Co.
  P.O. Box 26729
  Richmond, VA 23260
  (804) 281-6456
  John F. Noll, President

- Telstat Systems, Inc.
  60 Hudson Street
  New York, NY 10013
  (212) 227-5082
  Bruce Hechler, President

- Telos Computing, Inc.
  3231 Ocean Park Blvd.
  Santa Monica, CA 90405
  (213) 450-2424
  Len Conger, President

APPENDIX D: COMPUTER MAINTENANCE SERVICES COMPANIES

APPENDIX D: COMPUTER MAINTENANCE SERVICES COMPANIES

VENDOR	CONTACT	COVERAGE	ADDITIONAL SERVICES	EQUIPMENT SERVICED
BORDER ELECTRONICS 1704 E. Paisano El Paso, TX 79923 915-532-2524	Walt Ditts - Manager Larry Hernandez - Computer Technician	Periodic or time and materials	Installation, relocation, site planning, warehousing, refurbishment, diagnostics	Compco minis and associated terminals, Singer printers, ITT ASC II Scope, CIP 2000 computer, Cincinnati Milacron minis, Hewlett-Packard 2100, DEC PDP-11 Series
BUSINESS PRODUCTS SERVICES, INC. 3214 S. Fair Lane Tempe, AZ 85282 or 701 E. Factory Suite D Tucson, AZ 85719 602-966-1192	Mike Butler - President	Periodic, on-site, time and materials	Installation and refurbishment	DEC PDP-11 Series, other minis and peripherals depending on parts availability, Philips systems
CIRCLE COMPUTER SERVICES, INC. 920 Remington Road Schaumberg, IL 60195 312-884-2424	Joseph Conroy - President	On-site (Chicago area only) and time and materials	Installation, relocation, customizing refurbishment	IBM 360, 370 and 303X, minicomputers, peripherals and terminals

VENDOR	CONTACT	COVERAGE	ADDITIONAL SERVICES	EQUIPMENT SERVICED
COMMA (Control Data Corporation) P.O. Box O Minneapolis, MN 55440 612-853-8100		On-site, temp. on-site, time and materials, periodic	Installation, relocation, site planning and mixed vendor diagnostics	IBM 360 (models 22, 30, 50, 65, 67, 75), 303X, System/3, 1400 series, 7000 series, 370 (models 135, 145, 155, 158, 165, 168, 165 II, 155 II) and peripherals
COMMUNICATIONS ENGINEERING CO. (Communications Industries, Inc.) P.O. Box 10186 Dallas, TX 75207 214-630-7500	Jim Watson - Technical Support Manager	On-site, temp. on-site, time and materials	Installation and relocation	Hazeltine, GE Terminet terminals, DG Nova, Interdata 16- and 32-bit minis, Wangco, Diablo, Ampex disks, Tally, Okidata printers, Mohawk data preparation equipment, Beehive terminals
COMPUTER HARDWARE MAINTENANCE CO. (CHC&S) 370 Pheasant Run Newton, PA 18940 215-968-5900	Claude Haring - President	On-site, temp. on-site, time and materials, periodic	Refurbishment, customizing, reconditioning, 360/370	360 (models 20, 22, 25, 30, 40, 50, 65) and peripherals, all 370 series and peripherals, DEC equipment and peripherals
COMPUTER HARDWARE SERVICE CO. 11 Vincent Circle Jacksonville Park Nyland, PA 18974 215-443-9220	Joseph Colyar - President	Off-site depot repairs, rebuilds, changes specifications	None	IBM 360, 370 and peripherals

VENDOR	CONTACT	COVERAGE	ADDITIONAL SERVICES	EQUIPMENT SERVICED
COMPUTER MAINTENANCE AND LEASING CORP. 1009 Twelve Oaks Center Wayzata, MN 55391 612-473-3608 800-328-3655	Robert Rich, Jr. - Vice President and General Manager	On-site	Engineering changes	IBM equipment of Data Processing and General Systems Divisions only
THE COMPUTER ROOM 3928 Beau d'Rue Drive Eagan, MN 55112 612-452-2567	Jim Sullivan - Maintenance Manager	On-site, temp. on-site, periodic	Refurbishment, customizing, depot repairs	IBM 5100 and S/3, DEC PDP-8, PDP-11, DG Nova, micros, Imsai, DEC printers, Research CRT terminals, Centronics printers, Qume and Diablo printers, Lear Siegler ADM-2 and ADM-3 CRTs
COMPUTER SYSTEMS SUPPORT CORP. 9112 Gaither Road Gaithersburg, MD 20760 301-424-7870	Lloyd Root - President	On-site, time and materials	Installation, relocation, customizing, refurbishment	Data General minicomputers, peripherals and terminals
COMSHARE, INC. (Hardware Systems Div.) 3001 S. State Street Ann Arbor, MI 48106 800-521-9388	Jesse Caravello - Division Vice President	On-site, time and materials	Installation, relocation, customizing, refurbishment	Sigma, Perkin Elmer, Interdata, IBM-type peripherals, Comshare multiplexor I/O processor, Ampex, Memorex and STC memories

VENDOR	CONTACT	COVERAGE	ADDITIONAL SERVICES	EQUIPMENT SERVICED
DATA ENTRY, INC. 775 Kirkman Road Suite 113 Orlando, FL 305-299-6535	Jim Walton - President Ira Orem - Marketing Manager	On-site, time and materials, on-call	Installation, relocation, training, refurbishing	Data General, DEC, General Automation, Scope Data, Digital Computer Control
DATASERV COMPUTER MAINTENANCE, INC. (Dataserv Equipment, Inc.) P.O. Box 9488 9901 Wayzata Blvd. Minneapolis, MN 55440 612-544-0335 800-328-2406	James Duning - Director, Maintenance Service	On-site	Installation, relocation, refurbishment, customizing	IBM General Systems Division products, IBM 370 family and peripherals, word processors
DIGITAL APPLICATIONS, INC. 708 S. Rosemont Road Virginia Beach, VA 23452 804-595-5484	Bill Shumate - Vice President	On-site, time and materials	System design, refurbishment, site planning installation	All Beehive terminals, DG Nova minis, Micom
DP SERVICES 2966 Teagarden Street San Leandro, CA 94577 415-351-0801	Jim Hoffman - President Lorne Blain - Vice President	On-site, time and materials, periodic	Refurbishment, warehousing, customizing	Marshall disks; Mohawk equipment, Juki equipment, most IBM peripherals (except typewriters), and IBM 1401 CPUs

VENDOR	CONTACT	COVERAGE	ADDITIONAL SERVICES	EQUIPMENT SERVICED
FORMATION, INC. 825 E. Gate Drive Mt. Laurel, NJ 08057 609-234-5020 or 4319 Covington Highway Decatur, GA 30035 404-288-7511	Arthur Beard - President William Rennie - Vice President David McNeil - Director of Technical Support	On-site	Installation, relocation, refurbishment	DEC and RCA mainframes, minis, peripherals and terminals
GENERAL ELECTRIC CO. (Installation and Service Engineering Division) 22 Technology Park Norcross, GA 33092 or P.O. Box 105064 Atlanta, GA 404-447-7738 or Installation and Service Division Section 950-17 Schenectady, NY 12345 602-264-1751	Vic Delisle, Jr. - Manager, National Computer Contract Administration	On-site, temp. on-site, time and materials, periodic	Installation, refurbishment, relocation, site planning, diagnostics	DEC, Data General, Honeywell, CDS, Mohawk Data, Diablo, Documation, Hewlett-Packard, Applied Digital Data, Micom Systems, Vadic Modems, Televideo, ECS Microsystems, GE Terminet, and Computer Transceiver Systems, most peripherals and terminals
GEORGIA COMPUTER CORPORATION (Sun Data, Inc.) 6185 S. Buford Highway P.O. Box 105046 Atlanta, GA 30348 404-449-6166 800-241-9882	John Grilly - President Dan Hendrix - Vice President	On-site	Installation, relocation, refurbishment, customizing	IBM General Systems Division Products, IBM 370, minis and peripherals

VENDOR	CONTACT	COVERAGE	ADDITIONAL SERVICES	EQUIPMENT SERVICED
GRUMMAN DATA SYSTEMS (Electronic Systems Maintenance) 1111 Stewart Avenue Bethpage, NY 11714 516-575-6650	Alan Andrus - Manager Walter Beagan - Marketing Manager	On-site, time and materials	Installation, relocation, customizing, refurbishment	DEC, DG, Texas Instruments, CDC, Pertec
INDEP, INC. 1690 Republic Road Huntington Valley, PA 19006 215-322-0222 800-523-8962	Aiden Lombard - General Manager John Gerrow - Marketing Manager Donald Lombard - Manager, Technical Operations	On-site, time and materials	Installation, relocation, refurbishment, customizing	IBM 370, 3000, 4300 and peripherals
INSTRUMENTATION INDUSTRIES, INC. 1211 Streets Run Road Pittsburgh, PA 15236 412-884-5161	Elgin Eissler - Vice President	On-site, temp. on-site, periodic	None	Zeta Research plotters, Kybe tape cleaners, Dataroyal line printers
INTEGRATED AUTOMATION, INC. 1745 Tully Circle N.E. Atlanta, GA 30329 404-325-8100	Huey P. Duncan - President	On-site, time and materials, periodic	Installation, relocation, site planning, diagnostics, warehousing, refurbishment	DEC PDP-11, Honeywell minis, CDC disks, Hazeltine CRTs and associated thermal printers and cassettes, Printec printer, Pertec disks, GE Terminet

VENDOR	CONTACT	COVERAGE	ADDITIONAL SERVICES	EQUIPMENT SERVICED
KALBRO CORPORATION 101 Foster Road Morristown, NJ 08057 609-778-1800	William Kane Director, Marketing	On-site, temp. on-site, periodic	Installation, relocation, site planning, warehousing, diagnostics, refurbishment	DEC, H-P, DG, Interdata, Microdata, Computer Automation, Digital Computer Controls, Cincinnati Milacron, Westinghouse minis and peripherals, Datapoint, ADDS, TI, terminals
J.H. LESKIN ASSOCIATES, INC. 2360 Avenue A Bethlehem, PA 18017 215-865-335-	Joseph Leskin - President	On-site, temp. on-site, periodic	Installation, relocation, site planning, warehousing, refurbishment	DEC PDP-8, Centronics, Data Products, DEC printers, Data 100, Pertec disks, key-to-tape and data transmission equipment, Singer point-of-sale equipment, Flexowriters, data collection equipment, Kybe tape perforators
LOONAM ASSOCIATES, INC. 720 Bush Lake Road Minneapolis, MN 55435 612-831-1616 800-328-4028	James Loonam - President Eugene Franklin - Division Marketing Manager	On-site, time and materials	Installation, relocation, refurbishment, customizing	ADDS, Anderson-Jacobson, DEC, Diablo, Hazeltine, Multitech, Penril, Teletype, Texas Instruments

VENDOR	CONTACT	COVERAGE	ADDITIONAL SERVICES	EQUIPMENT SERVICED
MAINTECH (Delta Resources, Inc.) 1133 Avenue of the Americas New York, NY 10036 212-944-3900	Frank Dalessio - Director Field Operations	On-site, time and materials	Relocation, refurbishment, customizing	Diva disk, Ampex magtape drives, DEC PDP-8 series PDP-11/70 series
MEMOREX CORPORATION San Tomas at Central Expressway Santa Clara, CA 95052 408-987-1000	Frank Juliano - Manager, Field Engineering Jerry Cavalier - National Accounts Manager, Third-Party Maintenance	On-site, on-call, temp. on-site, time and materials	Installation, relocation, site planning, consulting, diagnostics, refurbishment, warehousing	IBM 370 (models 158, 168), and System/3, IBM communications communications processors (3704, 3705), DEC PDP-11 and associated peripherals
MINI-COMPUTER SYSTEMS, INC. 399 Fairview Park Drive Elmsford, NY 10523 914-592-8812	Steven Eskanzi - National Field Service Manager	On-site, time and materials	Installation, relocation, refurbishment, customizing	Data General, Nova II and III, Control Data, Diablo disk drives, Data Printer, Printronix, Hazeltine terminals
MINI-MAINTENANCE INC. (Computer Election Systems, Inc.) 3020 Lincoln Court Garland, TX 75041 214-271-1577 800-527-4841	Charles Mitchell - President Bronson Allen - Vice President	On-call	Depot repairs (Dallas and Los Angeles), rebuilding, specification changes	Data Products, DEC, DG, Perkin-Elmer, CDC disk drives, Computer Automation

VENDOR	CONTACT	COVERAGE	ADDITIONAL SERVICES	EQUIPMENT SERVICED
PERTEC SERVICES DIVISION (Pertec Computer Corporation) 12910 Culver Road Los Angeles, CA 90066 213-822-9222	Pat Lydon - Vice President and General Manager Paul Sorensen Marketing Manager	On-call	Installation, relocation, site planning, consulting, refurbishment	DEC PDP-8, PDP-11, Digital Computer Controls, associated peripherals, other minicomputer systems, equipment by Caldata, Wangco, Conrac, Motorola, Infoton, Ann Arbor Terminals, Documation, GDI, Diablo, Calcomp, Memorex, Burroughs, Centronics, Data Products, Control Data
RCA SERVICE COMPANY (RCA Corporation) Government Services Division Bldg 202-1 Route 38 Cherry Hill, NJ 18358 609-338-6489	H. Rosenthal Manager, Planning and Development, Army and	On-site, temp. on-site time and materials, periodic	Facilities management, installation	All types of electronic and electric equipment and systems.

VENDOR	CONTACT	COVERAGE	ADDITIONAL SERVICES	EQUIPMENT SERVICED
RCA SERVICE COMPANY (RCA Corporation) Data Services Division Bldg 204-2 Cherry Hill, NJ 08358 609-338-5555	H. Shannon, Marketing Manager	On-site, temp. on-site time and materials periodic	Installation, relocation, site planning, diagnostics, warehousing, refurbishment	DEC-II Series, Honeywell H516, Printronix, Tally, Teletype, Centronics, G.E. Terminet, Hazeltine Diablo
SERVITECH, INC. 1409 Centre Circle Drive Downer's Grove, IL 60515 312-620-8750	S. Michael Smith - President James Weldon - Service Manager	On-site, temp. on-site, time and materials, periodic	Installation, relocation, site planning, refurbishment, warehousing, diagnostics, board repair	DG Nova and Eclipse systems, peripherals, General Automation, ment, General Auto- Computer Automation Digital Computer Control minis, Diablo disks, Ampex 980, CDC 9760, 9762, Wangco T&F series, Dataproducts 2230, 2260, 2250, and Data Printer printers, Diablo HyType II, Okidata, Odec, Tally 2000 series, Centronics 101, 102, 500, 300 series, Hazeltine 2000, 1000 CRTs, LSI ADM-1, ADM-2, Beehive terminals, GE Terminet DEC writers

VENDOR	CONTACT	COVERAGE	ADDITIONAL SERVICES	EQUIPMENT SERVICED
SIRVESS, INC. 23B Just Road Fairfield, NJ 07006 201-575-6650	Gene Snelling - President William Babb - National Sales Manager	Temp. on-site, time and materials	Installation, relocation, refurbishment, diagnostics	CDC 6000/Cyber series systems and peripherals, Univac 9200, 9300, 1004, 1005, 1050, 1107 systems, RCA spectra systems and peripherals, Xerox Sigma 2, Sigma 5, SDS 900, IBM 1401 and peripherals, DEC system 10 and 20, plus all current DEC equipment, except PDP-15, all DG, Interdata, Varian, General Automation, Computer Automation, and Digital Computer Controls
SORBUS, INC. (Management Assistance, Inc.) 150 Allendale Road King of Prussia, PA 19406 215-296-6000	Stephen Keane - President Marvin Venable - Vice President, Marketing	Time and materials, temp. on-site, periodic	Installation, relocation, site planning, refurbishment, warehousing, diagnostics	IBM equipment from keypunches to 370/155 and peripherals, 360 models 20, 22, 25, 30, 40, 50, 65, 195 and peripherals, add-on memories, Diablo terminals, IBM System/3, DEC and DG minis,

VENDOR	CONTACT	COVERAGE	ADDITIONAL SERVICES	EQUIPMENT SERVICED
STAFF COMPUTER TECHNOLOGY CORPORATION 10457 Roselle Street San Diego, CA 92121 714-453-0303	Lou Benton - President Roger Buack - Service Manager	On-site, temp. on-site, time and materials, periodic	Site planning, consulting, special interfaces	DEC Systems, Digital Computer Controls, DG Nova, Interdata, CDC - no IBM or Burroughs
SYSTEC, INC. 2715 Navigator Avenue Sanford, FL 32771 305-323-0230 800-327-2202	George Fletcher - President	On-site, time and materials	Installation, relocation, customizing, refurbishment	IBM 360, 370 DEC, Hewlett-Packard, memories of STC, Calcomp, Memorex
TELEFILE COMPUTER PRODUCTS, INC. 17131 Daimler Street Irvine, CA 92714 714-557-6660	Donald Hyde - National Service Manager	Installation, relocation, site planning, refurbishment	On-site, time and materials, periodic	Xerox systems and peripherals, GE 400 and 600 and peripherals, CDC 3200, 3300 DEC PDP-II, DG
THREE DELTA CORPORATION 1038 Kiel Court Sunnyvale, CA 94086 408-734-2680	Michael Amanatullak - President George Hayashad - Vice President	On-site	Specification changes, depot repairs and rebuilding	DEC and Data General equipment
TOTAL TECHNICAL SERVICES CO. (Computer Investors Groups) 181 E. Halsey Road Parsippany, NJ 07054 201-428-9393	William Whitworth - Vice President, Marketing and Field Service William Behrens - Marketing Manager	On-site, time and materials	Relocation, installation, refurbishment, customizing	IBM 360, 370, 303X and Intersil add-on memories

VENDOR	CONTACT	COVERAGE	ADDITIONAL SERVICES	EQUIPMENT SERVICED
TRW CUSTOMER SERVICE DIVISION (TRW, Inc.) 70 New Dutch Lane Fairfield, NJ 07006 201-575-7110	Maynard Smith - Vice President & Division Manager Robert Grismond - Director, Marketing	On-site, time and materials	Installation, relocation, refurbishment, customizing, printed circuit board repair	Singer, Docutel, ADDS, Hazeltine, IBM 360, 370, Honeywell
TYMSHARE EQUIPMENT SUPPORT (Tymshare, Inc.) 20705 Valley Green Road Cupertino, CA 95014 408-446-7000	John Swarbuck - Manager, Field Engineering	On-site, temp. on-site, demand, tailored	Installation, relocation, site planning, power hardware diagnostics	Xerox systems, DEC PDP-10s, PDP-11s, PDP-8s, all Varian series, all Interdata series minis, IBM compatible peripherals such as Ampex, ISS, Memorex, Calcomp disks, Storage Technology drives, and Intel Memories

APPENDIX E: ZERUST VAPOR CAPSULE EVALUATION

NORTHERN INSTRUMENTS CORPORATION

SWITCHGEAR BOXES - VAPOR CAPSULES EVALUATION

The attached describes the results of a series of tests on ZERUST Vapor Capsules carried out in Japan. In this test capsules were placed in electrical switchgear boxes and the boxes were subjected to the following conditions:

- salt spray
- temperature and humidity cycling
- constant heat and humidity
- corrosive gases

also observed was the effect of ZERUST vapors on solder and relay contacts.

As you will note, the test results were quite favorable.

NORTHERN INSTRUMENTS CORPORATION

Vincent J. Graziano
Name

Vincent J Graziano
Signature

President
Title

May 31, 1979
Date

ZERUST VAPOR CAPSULE EVALUATION - JAPAN, 1978

A. Overall Objective and Scope of Evaluation

To ascertain the corrosion inhibiting effectiveness of ZERUST Vapor Capsules in accelerated laboratory tests for the purpose of utilizing them in equipment situated in factory areas with high humidity and corrosion atmospheres.

B. Specific Objective and Tests

1. Objective

To determine the corrosion resistance of ZERUST Vapor Capsules in a seaside location.

Test Method

A 3 cycle test was performed where enclosures with test specimens* were subjected to a 5% salt spray for 6 hours and left standing for 16 hours (MIL-STD-101D for 72 hours).

2. Objective

To determine the corrosion resistance and stability of ZERUST Vapor Capsules in a tropical environment.

Test Method

Test specimens were subjected to the following cycling: 25°C — 65°C — 25°C — 65°C — 25°C — -10° — 25°C in a relative humidity of 90-98% (MIL-STD-106D for 10 cycles).

3. Objective

To determine the corrosion resistance of ZERUST Vapor Capsules in an environment of constant heat and humidity

Test Method

Test Specimens were subject to 40°C ± 2°C and 90-95% relative humidity for 240 hours (MIL-STD-103B).

4. Objective

   To determine the effect of ZERUST vapors on solder.

   Test Method

   The tin, gold, copper and specimens from test 1 - 3 above were tested regularly for soldering wetness using a Meniscograph.

5. Objective

   To determine the corrosion resistance of ½ gram COR-TABs in a corrosive environment.

   Test Method

   Test specimens were subjected to fumes of H_2S, NO_x, HCl and NH_3.

6. Objective

   To determine the effect of ZERUST Vapor Capsules on the contact resistance of relays.

   Test Method

   The contact resistance of a typical relay, 24 VDC, protected by ZERUST Vapor Capsules was checked after 30,000, 100,000, 300,000 and 500,000 make/break operations and compared to an unprotected relay.

   The relay (Diagram 2) was tested in the circuit shown in Diagram 1. The circuit cycled 9 times per second.

C. Test Results

1. In the 5% salt spray test there was marked corrosion on the unprotected iron, aluminum, brass and copper specimens. However on the ZERUST protected samples, the iron and aluminum were only slightly rusted, while brass and copper suffered no corrosion, not even discoloring.

2. In the temperature and humidity cycle test there were no characteristic changes in the protected specimens.

3. In the constant heat and humidity test, while the ZERUST protected iron and copper specimens were not completely unchanged as they were in test 2 above, there was a great difference between the unprotected specimens and the ZERUST protected specimens. As a result, the ZERUST Vapor Capsules were deemed particularly effective in such conditions.

4. The ZERUST vapors had no effect on soldering applied to the test specimens.

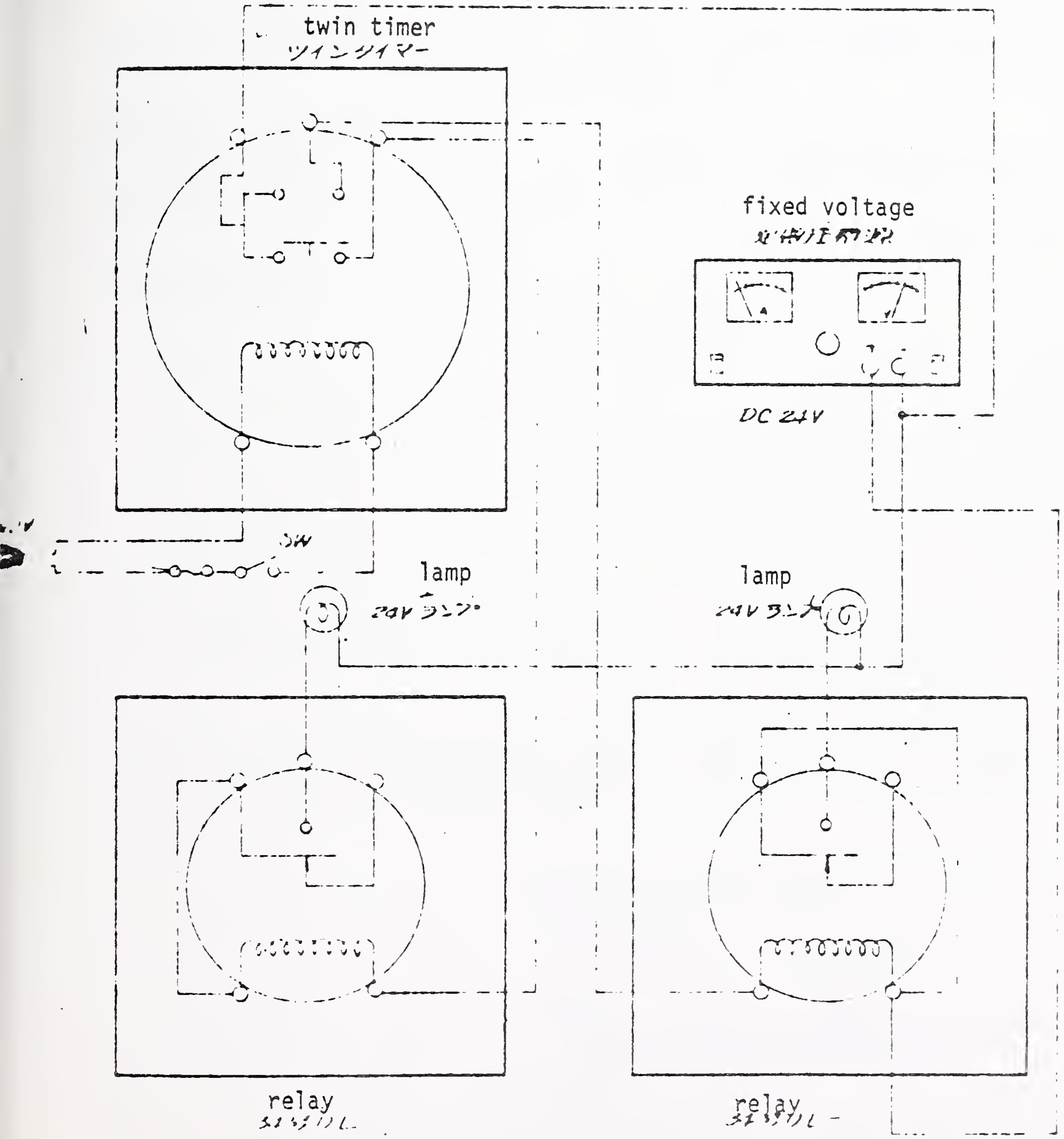
5. The corrosive environment tested showed that the ZERUST vapors would effectively neutralize H_2S vapors on a long term basis up to a concentration of 0.5 ppm. Short term protection could be expected if the concentration rose to 1.0 ppm. In a typical control room of a steel plant or refinery H_2S concentrations have been measured at 0.05 ppm.

6. The relay test showed that there was absolutely no change in contact resistance of a protected relay.

* Test Specimens -

Fe - iron
Al - aluminum
Bs - brass
Zn - zinc
Ni - nickel
Cr - chromium
Sn - tin
Ag - silver
Au - gold
Cu - copper

Diagram #1
図-1



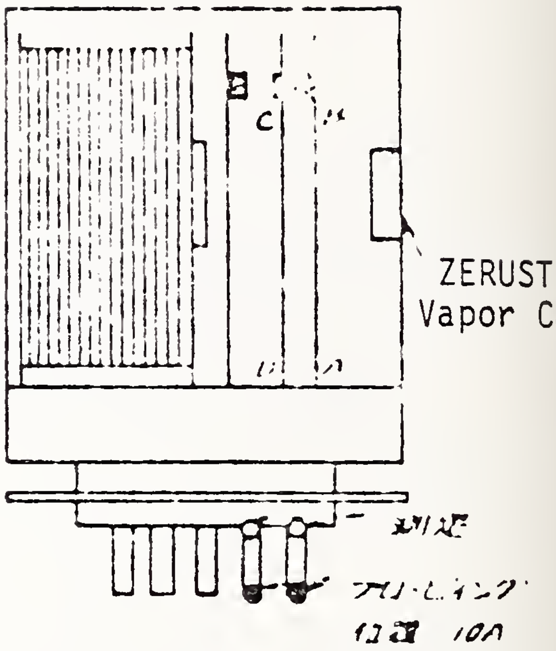
Protected by ZERUST
Vapor Capsule

（ブランク用）
unprotected

Caution
（注意）

右図の Point をプロービングし接触抵抗を測定するが、A～B間 C～D間の導体抵抗も測定され、純な接触抵抗値とはならないが、この場合 A～B、C～D間の導体は SHUR-SAFE に腐食されることはないので導体抵抗は一定とし、変化した分が接触抵抗値変化としてカウントするものである。

Diagram #2
図 2



Switch gear box

NORTHERN INSTRUMENTS CORPORATION

PACKAGING, SMALL ARMS - HUMIDITY EXPOSURE TRIALS

The following pages list the results of a series of tests wherein various preservative systems were evaluated for protecting small arms against humidity.

The tests were performed by the Canadian Department of National Defense. The humidity cycle to which all samples were subjected was that of MIL-STD-810C, method 5021, procedure V. This procedure called for 480 hours of temperature cycling between 23°C and 54°C in 90 to 95% Relative Humidity.

The results are reported in terms of

- control number assigned to weapon
- serial number of weapon
- type of wrapping into which weapon was placed
- Type of corrosion inhibitor product (preservative) tested
- condition of weapon at conclusion of test
- what preparation was required to issue the weapon for use

The tests show the excellent results obtained using ZERUST Vapor Capsules (identified in these tests as NIC-1 and NIC-2) in these severe test conditions.

NORTHERN INSTRUMENTS CORPORATION

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May 30, 1979
Date

Comments:

1. It was evident from the condition of the cardboard boxes and the swollen and warped woodwork that the test conditions were very severe. Any of the weapons that survived the test would certainly last for an extended period of time under normal storage conditions.
2. The poly type barrier material has the added advantage of being able to read the serial numbers without disturbing the preservation.

ANNEX A
TO LETE 7995-0 (E Sqn)
DATED 8 DEC 78

RESULTS OF WEAPON EXAMINATION

CONTROL NUMBER	SERIAL NUMBER	WRAP	PRESERVATIVE	CONDITION	PREPARATION REQ PRIOR TO ISSUE
1	4L5296	43-GP-30 Poly Bag	NIC-1	No rust or corrosion	None
2	3L6558	43-GP-30 Poly Wrap	31-GP-3	No rust or corrosion on weapon. Beads of moisture inside of wrap.	Complete stripping and cleaning with solvent (1 hr.)
3	4L3026	Anox Wrap (VCI)		Wrap paper wet, weapon wet, weapon very rusty, woodwork mouldy.	Not acceptable for issue.
4	0L5206	43-GP-30 Poly Wrap	31-GP-3	No signs of any rust or corrosion.	Complete stripping and cleaning with solvent (1 hr.)
5	3L3487	43-GP-30 Poly Bag not sealed	3-GP-335 and NIC-1	No signs of any rust or corrosion. Water beads in bag.	None
6	7L6182	Anox Wrap (VCI)	3-GP-335	Woodwork mildewed and swollen.	Not acceptable for issue.
7	1L1391	43-GP-30 Poly Bag sealed	3-GP-335 and NIC-1	Two small rust spots on exterior of butt plate, no signs of rust anywhere else.	None
8	2L4434	43-GP-30 Poly Bag	NIC-2	Rust on butt plate due to break in bag.	None
9	6L2927	Anox Wrap (VCI)	3-GP-335	No signs of any rust or corrosion on metal parts. Woodwork was mouldy and warped.	Not acceptable for issue.

CONTROL NUMBER	SERIAL NUMBER	WRAP	PRESERVATIVE	CONDITION	PREPARATION REQ PRIOR TO ISSUE
10	6L3465	VCI	3-GP-335	Wrap paper was damp, beads of water on interior of weapon, slight traces of rust in butt plate and trigger mech, woodwork mouldy and warped.	Not acceptable for issue.
11	1L7192	43-GP-30 Poly Wrap	3-GP-335	Surface rust on most of interior and exterior of weapon, moisture beads on 50% of weapon.	Not acceptable for issue.
12	4L6198	43-GP-30 Poly Bag sealed	NIC-1	Interior parts had a light coating of long term preservative although this was not indicated on the test label. No sighs of rust or corrosion.	Field strip and wipe off (20 min)
13	0L5718	43-GP-30 Poly bag taped at one end	NIC-2	Some beads of moisture in the bag at the taped end. No signs of any rust or corrosion.	None
14	6L4140	VCI	3-GP-335	Rust on flash eliminator and breechblock carrier exterior, woodwork mildewed.	Not acceptable for issue.
15	6L6279	43-GP-30 Poly Wrap	3-GP-335	No signs of rust or corrosion	None
16	6L8991	43-GP-30 Poly Wrap	3-GP-335	No signs of rust or corrosion.	None
17	4L5898	Anox Waxed Wrap (VCI)		Wrap paper damp, exterior surfaces rusted, foresight area badly rusted, no traces of rust on interior working parts.	Not acceptable for issue.
18	6L2358	43-GP-30 Poly Bag scaled	3-GP-335 and NIC-2	No signs of rust or corrosion.	None
19	3L5754	43-GP-30 Poly Wrap	3-GP-335 and NIC-2	No signs of any rust or moisture.	None

CONTROL NUMBER	SERIAL NUMBER	WRAP	PRESERVATIVE	CONDITION	PREPARATION REQ PRIOR TO ISSUE
20		43-GP-30 Poly Bag	RESIST-X	Very slight trace of rust on one end of piston spring, none in gas cylinder, no other signs of rust. Slight build-up of gummy preservative under woodwork, none in working parts.	Could be issued and cleaned by user in 15 min.
21		SARNEX-21 Poly Wrap	31-GP-3	No rust or moisture.	Complete stripping and cleaning with solvent (1 hr.)
22		SARNEX-21	31-GP-3	No rust or moisture.	Complete stripping and cleaning with solvent (1 hr.)
23		SARNEX-21	RESIST-X	No rust or moisture, slight build-up of gummy preservative under butt plate and in trigger mechanism	Easily removable in 15 minutes.
24		Anox Waxed Wrap	3-GP-335	No rust or moisture.	None
25		43-GP-30 Poly Wrap	RESIST-X	No rust or moisture.	Easily cleaned in 15 minutes.
26		Anox Wrap (VCI)	3-GP-335	No rust or moisture.	None
27		Anox (VCI)		Heavily rusted.	Not acceptable for issue.
28		Anox (VCI)		Weapon rusted interior and exterior, wrap paper damp.	Not acceptable for issue.

NORTHERN INSTRUMENTS CORPORATION

INTEGRATED CIRCUITS AND ELECTRONIC COMPONENTS
-VAPOR CAPSULE EVALUATION-

Humidity and a corrosive environment have adverse effects on integrated circuits, circuit board soldering and various electronic components. The attached describes the detailed results of an extensive evaluation of the anti-corrosion effectiveness of ZERUST vapors. The tests were performed in Japan by the Taiyo Petroleum Gas Co. Ltd.

We are pleased to report that the tests showed that ZERUST Vapor Capsules performed excellently in all respects. The vapors, while providing the requisite protection against corrosion, did not have any side effects on the non-electrical materials normally found with integrated circuits such as connector insulation, epoxy, plastic housing, etc.

NORTHERN INSTRUMENTS CORPORATION

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August 16, 1979
Date

ZERUST VAPOR CAPSULE EVALUATION

Test Conditions

Tap water was placed in a large glass container. Two ZERUST VCI-1 Vapor Capsules were then suspended in the container near its top. The capsule vapors were allowed to saturate the interior of the container for a 48 hour period before the test components were introduced into it. The test components were then placed on a wire mesh suspended above the water line. The test temperature was maintained between 102°F (25°C) and 108°F (28°C). Relative humidity varied between 95% and 98%.

The status of the integrated circuits was checked after 2200 hours. The remaining components were checked after 4000 hours, the results of which are listed in the following pages.

MATERIAL	TEST RESULTS
1. I.C. SN7405 (TTL TI)	
Plastic Container	normal
(silver plate)	normal, no corrosion
Performance	A.C. test - as specified D.C. test - as specified (100 pieces)
2. Printed Circuit Board	
Soldering Pattern	normal, no corrosion soldering normal
Connector Tubing (gold plate)	normal
Epoxy (FR-4)	normal, no warping or discoloration
Soldering Resistance	normal
Soldering	satisfactory
3. Connector	
a) M Connector (AMP)	
Terminal (gold plate)	normal
Housing (phenol resin)	normal, no deformation or discoloration
Metal Latch Fittings	normal
Printed Name	printing normal
Resistance	4M ohm - as specified
b) CIS Connector (AMP)	
Terminal (foil)	normal
Housing (plastic)	normal, no deformation or discoloration
Resistance	5M ohm - as specified
c) Flat Cable Connector 3418-0000T (Sumitomo-3M)	
Terminal (tin)	normal
Housing (plastic)	normal, no deformation or discoloration
Resistance	4M ohm - as specified
d) Flat Cable Connector 65483-028	
Terminal (gold plate)	normal
Housing (plastic)	normal, no deformation or discoloration
Resistance	6M ohm - as specified

MATERIAL	TEST RESULTS
4. Terminal	
a) TBS Type	
Terminal (tin)	normal
Housing (Diallyl Phthalate)	normal, no deformation or discoloration
Resistance	6M ohm - as specified
b) Y Type	
Terminal (tin)	normal
5. Wire and Cable	
a) Flat Cables	
Soft Vinyl Cover (tin foil wire)	normal, no discoloration or deterioration soldering - satisfactory insulation > 1000 M ohms
b) Ribbon Cable	
PVC Covered Wire (tin foil wire)	normal, no discoloration or deterioration soldering - satisfactory insulation > 1000 M ohms
c) Ylax Wire (overbridge polyethylene wire)	
0.3, 0.5 mm^2 (tin foil) 0.5 mm^2 twisted pair	normal, no discoloration or deterioration soldering - satisfactory insulation > 1000 M ohms
d) Overbridge Polyethylene Single Core	
Nylon Wire (tin foil wire)	normal, no discoloration soldering - satisfactory insulation > 1000 M ohms
e) 3 Wire Cord (Kawasaki N. CSA Type	
PVC Coated AC (copper)	normal, no discoloration or deterioration soldering - satisfactory insulation > 1000 M ohms

	MATERIAL	TEST RESULTS
f)	2 Wire Sealed Cord PVC and Polyethylene coated (tin foil wire)	normal, no discoloration or deterioration soldering - satisfactory insulation > 1000 M ohms
g)	Choke Transformer Wiring Coated Copper Wiring with soldered tips	normal, no discoloration or deterioration soldering - satisfactory insulation > 1000 M ohms
6.	Miscellaneous Electronic Components	
a)	Choke Transformer (TDK) Nylon Bobbin Copper Alloy Fixturing	normal, no discoloration or deterioration soldering - satisfactory inductance - as specified
b)	Relay (Matsushita Den-ko) NF4E-24V AE 135-44 Plastic Sealed Relay	normal, no discoloration or deterioration movement - normal terminal soldering-satisfactory contact resistance 25M ohms
c)	Switch (Nikkai) SP-2012 type 6A, 125VAC with 2 plastic keys	normal, no discoloration or deformation on/off resistance - satisfactor terminal soldering-satisfactory
d)	Condenser (Matsuo) Metallized Polyester Coating FNX-HO, 22K, 200V	normal, no discoloration or deformation soldering - satisfactory capacitance - as specified
e)	Condenser (Matsuo) Wet Tantalum 200 uf 25V Tin Plated Leads	normal, no discoloration or deformation soldering - satisfactory capacitance - as specified

MATERIAL	TEST RESULTS
f) Resistor 150K ohm	normal, no discoloration or deformation soldering - satisfactory resistance - as specified
g) Switch (Digitran) Plastic Housing	normal, no discoloration or deformation movement and resistance - satisfactory
h) Bobbins With Polyester Coated Leads	normal, no discoloration or deformation soldering - satisfactory resistance - 500 ohms as specified
Lead Insulation Contains Silk	normal, no discoloration or deformation soldering - satisfactory resistance - 500 ohms as specified
i) Power Transistor 2SD 417	normal, no discoloration or deformation soldering - satisfactory
7. Miscellaneous Electrical Supplies	
a) Teflon Conduit	normal, no discoloration or deformation
b) Vinyl Conduit (clear)	normal, no discoloration or deformation
c) Coil Plug (nylon)	normal, no discoloration or deterioration
d) Rubber Door Gasket (with adhesives)	normal, no discoloration or deterioration
e) Acrylic Circuit Board (clear and green)	normal, no discoloration or deterioration
f) Vinylchloride Base	normal, no discoloration or deterioration
g) Circuit Board Guide (Polyester Carbonate)	normal, no discoloration or deterioration

NORTHERN INSTRUMENTS CORPORATION

Laboratory and In-Field Evaluation of Vapor Capsules* - Kansai Electric Power Company, Japan

The attached describes the results and provides photographic documentation of evaluations of the protection afforded by Northern Instruments vapor capsules. Two series of tests were conducted, the first were performed in the LABORATORY, the second series in actual FIELD conditions. Hence the importance of these results. The test data and accompanying photographs were provided by Kansai Electric Power Company of Japan.

We are pleased to provide you with the impressive results of these comparative tests.

NORTHERN INSTRUMENTS CORPORATION

Vincent J. Graziano
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August 13, 1979
Date

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* In Japan ZERUST Vapor Capsules are distributed under the brand name "STOR-SAFE".

Overall Conclusion

Vapor phase corrosion inhibitors have been manufactured and widely used in Japan since 1958. To date, the most well known of these inhibitors is Dicyclohexylammonium nitrite, often referred to by its briefer designator, DICHAN. This product is known to be effective on ferrous and ferrous alloys, but it attacks many non-ferrous metals and additionally requires as neutral an environment as possible when used. However as it is a recognized inhibitor it was decided to include it in these tests and compare the effectiveness of STOR-SAFE vapor capsules to that of DICHAN.

After months of testing, ZERUST Vapor Capsules were shown to outperform DICHAN in every test. As a result Kansai Electric Power stated to us that "STOR-SAFE is a very effective vapor phase anticorrosive agent for protecting industrial meters and similar electrical equipment made of ferrous and/or non-ferrous materials under various types of weather conditions.

Laboratory Tests

Laboratory tests were performed under conditions designed to accelerate the development of corrosion. These tests were conducted at the Kansai Electric Research Laboratory and the Taiyo-Ekka Gas Company.

The test materials were as shown below:

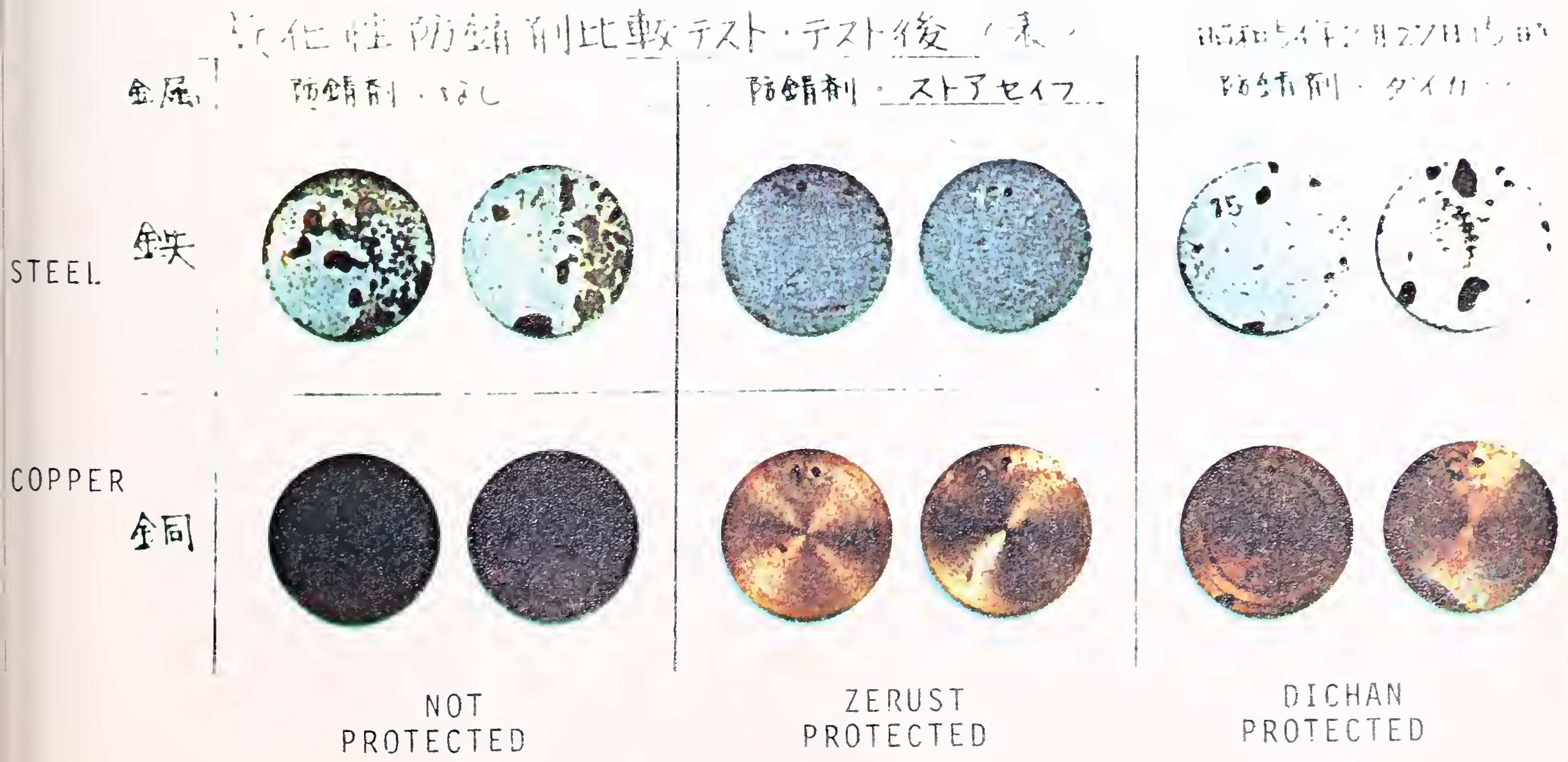
Material	Size	JIS Gauge	Quantity
Mild Steel	30mm x 2mm	JIS G 3101 SS41	6 pcs.
Copper	30mm x 2mm	JIS H 3250 99.96%	6 pcs.

In the tests two specimens were protected by a ZERUST VC 1-1 capsule, two specimens were protected by an amount of DICHAN equivalent to the quantity of the inhibitor in a ZERUST VC 1-1 capsule, and two specimens were not protected.

The test specimens were sealed in containers with 500cc of distilled water and 50ppm of H_2S gas and subjected to temperature cycling from 15°C (59°F) and 50°C (122°F) for one month.

Photographs of the specimens were taken at the conclusion of the test and are shown in Exhibit 1 below.

Exhibit 1



Field Tests

Field tests were performed in power stations situated close to a petrochemical refinery, a seaport and a chlorination facility. Steel and Copper specimens were placed in pairs of electrical switching boxes. In each case one of the boxes was protected by a ZERUST VC 2-1 capsule and the other was left unprotected.

The results of these tests verified those obtained in the laboratory.

APPENDIX F: GAO PROVISIONAL CHECKLIST FOR SOFTWARE DEVELOPMENT CONTRACTING

APPENDIX F: GAO PROVISIONAL CHECKLIST FOR SOFTWARE DEVELOPMENT CONTRACTING

- This checklist was obtained from GAO Report FSMSD-80-4, 11/9/79, Contracting for Computer Software Development.

- This checklist covers items that management should consider when contracting for computer software development. The checklist is divided into five contract phases: pre-contract, contracting, proposal evaluation, performance period, and post-contract.

- While this checklist is only an interim document, it will be useful to personnel involved in contracting for software development.

- Some of the points included in this list might apply to contracting for any type of service and may be covered in general procurement guidance. Those points are listed here to make the list complete and to emphasize that they can indeed be applied to software development contracts as well as to others.

A. PHASE: PRE-CONTRACT

1. OBJECTIVE

- To obtain realistic assessments of the size, scope, and cost of the effort to produce the needed software.

a. Methods

- Describe the needed software as completely as possible in the request for proposal so that the contractor can understand and address the full scope of work in his proposal.

- Describe the software so that people not familiar with agency operations can understand the need.

- Develop criteria to evaluate how reasonable and accurate the contractor's costs are.

b. Procedures

- Include all details from the system development steps completed by the agency to date.

- In the areas where detailed specifications have not been developed, clearly state the functional requirements the software must satisfy.

- Give all known constraints and parameters the vendor must work with in developing the software.

c. Possible Ways of Accomplishing the Procedure

- The use of agency jargon, which might be unclear to outsiders, should be avoided.

- A contractor's accounting system must be determined to be adequate to generate valid cost estimates.

- The cost of past development efforts may be compared to current proposed costs.

- Caution should be exercised on bids that are much higher or lower than the average of bids received.

2. OBJECTIVE

- To insure the contractor most suited to do the work is selected.

a. Method

- Develop comprehensive proposal evaluation standards to use in identifying nonresponsive bidders and in selecting a qualified contractor.

b. Procedures

- Consider the contractor's management qualifications.
  - Does the contractor's organization reflect adequate management overall?
  - Is adequate management available for this project?
  - Will the staff responsible for the proposal also work on the project?
  - Is the responsibility for this project at a high enough level of authority in the contractor's organization?
  - Is it likely that key personnel will remain with the project from start to finish?
- Consider the contractor's technical approach.
  - Does it reflect a knowledge of the agency's mission and functions?

  - Will the proposed software take full advantage of the agency's latest computer hardware capability?

  - Does the contractor use software performance measurement tools and techniques as well as software optimization tools to insure the most efficient development possible?

  - Does the technical proposal rely on state of the art or unproven methodology as opposed to proven technology?

  - Is the overall design sound and feasible?

- Consider the contractor's quality assurance program.

  - Does the contractor have a documented program in effect that will ensure that the software meets contract specifications?

  - Is contractor quality assurance measurement compatible with the agency acceptance criteria for the final product?

- Consider the contractor's cost proposal.

  - In doing so, refer to the criteria in the first objective of this phase.

B. PHASE: CONTRACTING

1. OBJECTIVE

- To initiate a framework for the software development that ensures the maximum chance for success by requiring that sound system development practices be followed.

a. Method

- Include in the contract a requirement that the contractor not bypass system development steps in the development process. This will provide a means for the agency to assure itself that the contractor is performing the required system development steps.

b. Procedures

- Determine the system development steps accomplished by the agency to date.

- Identify the remaining system development steps to be accomplished by the contractor.

- Specify the sequence in which these steps are to be accomplished.

c. Possible Way of Accomplishing the Procedures

- As part of the deliverables that the contractor must provide, include a product at the end of each system development step which demonstrates that the step has been satisfactorily completed. These products would include preliminary surveys, feasibility studies, general and detail design, test data and test plan, the actual programs, and acceptance test results.

2. OBJECTIVE

- Write a contract which clearly states the obligations of both the agency and the contractor.

a. Methods

- Specify in the contract's statement of work who has the responsibility for each task.

- Specify in the contract what constitutes satisfactory performance by the contractor.

b. Procedures

- All agency obligations should be included in the milestone chart and their performance period should be specified the same as the contractor's.

- Tasks should be scheduled so that agency work that is prerequisite to contractor performance will not delay the contractor.

- The contract should provide for phasing the software from the contractor to the agency, including agency training and briefing the staff during the work.

c. Possible Ways of Accomplishing the Procedure

- Whether the specifics of the software are known or not, satisfactory performance should be quantified in terms of all known requirements and constraints. Some areas for performance standards are the:

  - Ability to meet agency's functional requirements.

  - Growth potential requirements of the system.

  - Time constraints for deliverables.

  - Test and acceptance criteria which must be met.

  - Programming language standards and practices to be followed.

  - Documentation standards to be followed.

  - Ease of modification.

  - Maximum computer resources allowed.

3. OBJECTIVE

- Write a contract which gives the agency the right and the visibility to manage the contract.

a. Methods

- Provide for a minimum of investment of funds before the quality of the contractor's work is known.
- Specify who is authorized to make changes in the contract.
- Provide some means to monitor the contractor's progress.

b. Procedures

- Phase the development into logical work steps.
- Require agency approval for each phase before beginning work on the next.
- The more undefined the software is, the closer the phasing steps should be at the outset.

c. Possible Ways of Accomplishing the Procedures

- Besides the contracting officer, specify management's technical representative who is authorized to make changes and to answer contractor's questions.
- Use phasing to assist in setting up a milestone chart showing the timeframe for each work step.
- Require the contractor to document the satisfactory completion of each workstep by the agreed date.

- Interim progress reports may be required from the contractor to allow progress to be monitored during each work step.

- Identify performance as well as functional specifications.

- Specify the measures of reliability and quality by which the contractor's work will be evaluated.

4. OBJECTIVE

- Write a contract which gives the agency some recourse if the contractor fails to perform.

a. Methods

- The contract should provide for the agency to terminate the contract if it becomes evident that the contractor cannot perform according to the contract's terms.

- The contract should also provide separate due dates and costs for each deliverable and a provision to withhold payment for incomplete or unacceptable work.

b. Procedure

- If agency evaluation of the contractor's work indicates that the approach being used will not produce the needed software, and if the contractor's work cannot be redirected, the contract should be terminated to minimize losses.

c. Possible Ways of Accomplishing the Procedures

- Satisfactory performance criteria, and acceptance testing criteria should be used to identify work that does not meet contract requirements.

- Payment to the contractor should be reduced by the amount of any deliverables (e.g., documentation) specified in the contract but not produced.

C. PHASE: PROPOSAL EVALUATION

1. OBJECTIVE

- Ensure that a skilled and responsible contractor is selected.

a. Method

- Only contractors with verified technical skill and financial responsibility should be selected to develop custom software contracts.

b. Procedure

- Agencies should evaluate each proposal in terms of relevant factors, including those listed below, and including considerations of feasibility, comparison to other proposals' prices and schedules and, if possible, comments solicited from the contractor's prior customers.

c. Possible Ways of Accomplishing the Procedures

- Include in the request for proposal a provision for agency representatives to visit the contractor site to investigate and evaluate various factors, including financial position, technical capability, and labor resources.

- Try to determine whether or not the contractor's capabilities, qualifications, and experience are commensurate with the complexity of the problem.

- Try to determine whether or not the contractor's staff has experience with the software and hardware to be used during development.

- Consider the effect on the contract schedule of the contractor's experience (e.g., delay in training the contractor's staff).

D. PHASE: PERFORMANCE PERIOD

1. OBJECTIVE

- The agency should manage the contract during execution in a manner that contributes to its success.

a. Methods

- The agency should provide all of its deliverables to the contractor within the specified timeframes.

- Management should create an environment within the agency that supports the contractor's efforts.

b. Procedures

- Such things as studies, requirements, and general designs to be provided by the agency should be provided promptly so that the contractor is not delayed.

- If provided by the agency, such work products should be complete, accurate and provide a basis for the contractor's work.

c. Possible Ways of Accomplishing the Procedures

- Management should be involved at high enough levels to insure cooperation by all agency personnel. If there is disagreement about the new development effort among various factions within the agency, it should be resolved in-house by management and not left for the contractor to encounter.

- If possible, the same agency staff should be kept on the project throughout the contract.

- A single focal point should be established within the agency to deal with the contractor.

- An open line of communication should be maintained with the contractor. However, undocumented informal communication can lead to cost overruns. Any changes in the scope of work must be handled by formal modification of the contract document.

2. OBJECTIVE

- Monitoring the contractor's progress to ensure that critical milestones are met and to approve work segments.

a. Methods

- Use timeframe criteria that are established to determine whether the contractor's development is on schedule.

- All work should be reviewed at the end of each completed phase to determine if it conforms with contract specifications.

b. Procedures

- Check progress against dates on the milestone.

- Be alert for signs of problems in the contractor's progress reports.

- Conduct any independent reviews of the contractor's operation that are considered necessary.

c. Possible Ways of Accomplishing the Procedures

- Consider how well agency requirements are met.

- Decide if the contractor's approach is technically feasible.

- Obtain users' evaluation of contractor's work.

- Render timely management decisions on all alternatives presented by the contractor.

- Once a phase is approved, freeze that phase until development is complete to stabilize the base for succeeding phases.

- Acceptance testing may be applied to completed phases as well as at the end of the development effort.

3. OBJECTIVE

- Do adequate testing to ensure that the product meets contract specifications.

a. Method I

- Make sure acceptance test criteria are still current.

- Maintain adequate control over the testing operation.

i. Procedure

- If test criteria and data were developed in the beginning, make certain they have been revised to incorporate system changes, if any.

ii. Possible Ways of Accomplishing the Procedures

- Observe or participate in software test.

- Adequately analyze the test results.

- Document all errors revealed by the test.

- Require the contractor to correct all discrepancies as a condition for final payment.

- Follow up on all discrepancies to make sure they are corrected before the system is accepted.

b. Method II

- Ensure that personnel responsible for testing the system have adequate technical expertise.

i. Procedures

- Assign qualified agency staff with systems, data processing, and performance evaluation expertise to test software.

- If the agency does not have the expertise to adequately evaluate the software, arrange for an independent evaluation by outside sources.

4. OBJECTIVE

- To exercise all remedies on behalf of the agency in case the contractor fails to perform.

a. Method

- Full payment should not be made to the contractor until it is determined that the software meets contract specifications.

b. Procedure

- Exercise the contract recourse provisions discussed under contract controls to the degree that nonperformance was encountered.

E. PHASE: POST-CONTRACT

I. OBJECTIVE

- Identify both good and bad aspects of the software procurement.

a. Method

- Make a followup analysis of the software development procurement contract to evaluate contracting practices, record lessons learned, and evaluate user satisfaction with the product.

b. Procedures

- Identify practices that are weak and need to be changed.
- Identify and retain practices that produced good results.
- Identify additional agency guidelines that need to be developed and implemented.
- Evaluate user satisfaction with the software.

- Record the actual amount of maintenance programming work that is needed soon after the software is put into production.

- Retain performance data on the individual contractor for future reference.

APPENDIX G: INTERVIEW PROGRAM

APPENDIX G: INTERVIEW PROGRAM

Company Type	On-Site Interviews	Telephone Interviews	Total
Ammunition Plants	7	-	7
EPCS Vendors	6	9	15
EPCS Users	5	9	14
Maintenance Service Companies	2	1	3
Other Vendors/Users	-	5	5
TOTAL	20	24	44

APPENDIX H: INTERVIEW GUIDES

INTRODUCTION

AMMUNITION PLANT SITE VISIT

INPUT has been retained by the U.S. Army to develop a maintenance format and program for electronic process controlled ammunition plants. This program is to be based upon the information available on both current and future commercial systems combined with current systems information in various ammunition plants around the United States.

This outline has been prepared to ensure that similar information is gathered at each plant site and to ensure that no important items are omitted. Items may be added that are felt to be pertinent to the subject. Reasonably detailed systems information is requested so that the subsequently proposed maintenance program will be most effective and appropriate for this site.

CATALOG NO. Y M D C ☐ ☐ ☐

AMMUNITION PLANT SITE DISCUSSION OUTLINE

PART I

I. Plant description.

- A. Plant name and address.
- B. Type of plant.
- C. How plant integrates with other plants.
- D. History of plant.
  - 1. State of construction/operation.
  - 2. Vendors involved.
  - 3. Level of automation.
  - 4. Start-up problems.
  - 5. Dates of construction, equipment, installation, etc.

IN

AMMUNITION PLANT DISCUSSION OUTLINE

PART 2

II. EPC system description.

A. Overview description.

B. Block diagram.

1. Plant.

2. EPCS.

3. Software.

C. Hardware.

1. Specific computer models.

2. Programmable controllers.

3. Interface models.

4. I/O equipment.

5. Communications equipment.

6. Instruments, sensors, flowmeters, measuring devices.

7. Other equipment.

8. Documentation available.

D. Software.

1. Standard programs.

a. Computer vendor supplied.

b. EPCS vendor supplied.

c. Documentation.

d. Storage media.

2. Custom software.

a. Vendor.

b. Documentation.

c. Standards.

E. Environment.

1. Operating.

a. Temperature.

b. Humidity.

c. Atmosphere.

d. Other factors--(example: vibration).

2. Dormant.

a. Temperature.

b. Humidity.

c. Atmosphere.

d. Other factors--(condition of neighboring facilities).

III. Operating experience.

A. Production running.

1. Time to reach maximum production rate.

a. Maximum potential.

b. Maximum achieved.

c. Average rate.

2. Downtime experience.

3. Reasons for failure.

a. Tracking failures.

b. Analysis.

4. MTTR—(possibilities for reduction).

5. MTBF--(possibilities for increase).

6. Plans for improvement.

B. Maintenance procedures.

1. Overall plan.

2. Actual implementation.

3. Changes based upon system performance.

4. Current posture.

5. Future plans.

6. Reliability estimating procedures.

7. Failure prediction techniques.

8. Critical areas.

IV. Reactivation experience.

A. Reactivation history.

B. Reactivation plans.

1. Testing.

2. Mobilization.

C. Dormant storage conditions.

1. Computers.

2. Controllers.

3. Measuring and communicating devices.

   a. Electromechanical.

   b. Optical.

   c. Electronic.

   d. Other.

4. Magnetic media.

5. Software.

6. Documentation storage.

V. Parts inventory management.

A. Parts listings--detail.

1. Detailed vendor listing.

B. Spare parts program.

C. Vendor support.

  1. Experience with vendors.

  2. Active—time period.

  3. Passive—time period.

D. Alternate parts sources.

E. Compatible parts assessment program.

VI. Personnel skills program.

A. Current skills assessment.

1. Operating personnel.

2. Maintenance personnel.

a. Hardware.

b. Software.

B. Reactivation skills required.

1. Hardware.

2. Software.

C. Personnel tracking program.

D. Personnel training program.

1. Frequency.

2. Techniques used or planned.

3. Trained cadre required.

4. Training vendors.

5. Sources of new personnel.

6. Personnel problems anticipated.

a. Planned solutions.

VII. Operating contractor's recommendations.

A. Improvement of operating environment.

B. Relationship with system vendors and subvendors.

C. Maintainability requirements.

D. Reactivation procedures.

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E. Equipment storage.

F. Spare parts management.

G. Personnel.

H. Training program.

I. Other.

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ELECTRONIC PROCESS CONTROL SYSTEM USER DISCUSSION GUIDE

INPUT has been retained by the U.S. Army Armament Research and Development Command to develop information to establish a methodology for the repair and maintenance of electronic process control systems that will be inactive over long periods of time.

The emphasis of this study is on the electronic control portion of the systems—the computer, the lines, the controller, the I/O subsystem, the sensors and the software.

The U.S. Army is interested in user's experience with respect to reliability and maintainability of commercial electronic process control systems. Special interest is directed towards those systems that are shut down for varying periods of time due to the closing of a production plant, the decommissioning of a battleship, or the cocooning of an aircraft. Any suggestions concerning the storage, reactivation, or maintainability of such systems are welcome. Comments in the areas of spare parts management and personnel development are also welcome.

In return for your assistance with this research, a summary of the key findings will be sent to you at the conclusion of the study.

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ELECTRONIC PROCESS CONTROL SYSTEM USER DISCUSSION GUIDE

I. General information.

A. System background.

1. Year of design.

2. Date of installation (acceptance).

3. System supplier/designer.

4. Software supplier.

5. System diagram.

B. System hardware.

1. Computer manufacturer and model.

2. Memory size.

3. Communication lines.

4. I/O equipment.

5. Mass storage—type, size, speed.

6. Sensors—number and type.

7. Programmable controllers.

C. Software.

1. Standard software source.

2. Custom software source.

3. Block diagram.

D. Back-up system.

1. Warm/cold.

2. Critical areas.

3. Equipment.

4. Data storage.

5. Communications.

6. Other considerations.

E. Fail-safe considerations.

1. Design.

2. Procedures.

3. Other.

F. Support.

1. From systems designer/contractor.

2. From computer manufacturer.

3. From software vendor.

II. Reliability experience.

A. History.

1. Initial start-up problems.

2. Problems after production running.

3. Failure prediction algorithms used.

B. Method for handling problems.

  1. Failure reporting and tracking system.

  2. Feedback loop for improving system.

3. MTBF.

4. MTSF.

5. MTTR.

6. Operator's responsibilities.

7. System designer's responsibilities.

8. Equipment manufacturer's responsibilities.

9. Software designer's responsibilities.

III. Maintainability.

A. Design features.

B. Preventive maintenance procedures.

1. Planned.

2. Reasons for modification.

3. Current procedures.

C. Personnel for maintenance.

1. Skills required.

2. Source of personnel.

3. Amount of core cadre necessary.

4. Training provided.

5. Future problems/solutions.

IV. Spare parts management.

A. Inventory.

1. How determined.

2. Frequency of change.

3. Current and average dollar value of inventory.

4. Storage conditions/packaging.

5. Average storage time for spares.

6. Maximum storage time for any part.

7. Recycling testing procedures.

8. Usage experience as a function of storage time.

9. Handling of "out of stock" conditions.

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B. Obsolescence.

1. Experiences.

2. Suppliers' policies.

3. Alternate sources.

4. Compatible parts assessment program.

5. Suggestions.

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V. Shutdown, dormancy and reactivation experience.

A. History.

1. Shutdown dates and reasons.

2. Length of dormant periods.

3. Dates of reactivation.

B. Conditions of dormancy.

1. Packaging.

2. Environmental.

3. Other.

C. Reactivation.

1. Plan.

2. Procedures.

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3. Precautions taken.

4. Problems encountered.

5. Solutions.

6. Feedback loop.

7. Other comments.

VI. Future.

A. Technological changes that affect process control systems reliability and maintainability.

B. If you did it over again, what would be done differently?

C. Advice for EPC system builders and users.

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ELECTRONIC PROCESS CONTROL SYSTEM VENDOR DISCUSSION GUIDE

INPUT has been retained by the U.S. Army Armament Research and Development Command to develop information to establish a methodology for the repair and maintenance of electronic process control systems that will be inactive over long periods of time.

The emphasis of this study is on the electronic control portion of the system--the computer, the lines, the I/O subsystem, the sensors and the software.

The U.S. Army is interested in which developments in future systems will tend to increase systems reliability and contribute significantly to the ease of maintaining these systems during long periods of inactivity. Any suggestions concerning present or future maintenance methodologies, spare parts management, and personnel development are welcome.

In return for your assistance with this research, a summary of the key findings will be sent to you at the conclusion of the study.

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ELECTRONIC PROCESS CONTROL SYSTEM VENDOR DISCUSSION GUIDE

I. General.

A. Size of electronic process control industry.

1. Number of major vendors.

2. Total industry dollar volume of business--1979.

3. Growth over last 10 years.

B. Major vendors.

1. Name and rank (sales in EPCS business only).

C. Major user industries.

D. Third party maintenance companies.

II. Currently available systems.

A. Reliability.

1. Considerations in design.

a. How are subunits selected.

2. Trade offs available.

3. MTBF.

a. Standard.

b. Means of maximizing.

c. Cost of maximizing.

d. Maximum achievable.

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e. Failure prediction algorithms.

f. Comments--(example: Major influencing factors.)

4. MIL-SPEC components.

a. Cost versus reliability.

b. Availability for EPC systems.

5. Other packaging techniques for components.

6. System/subsystem/device weak points.

   a. Reason.

   b. Design to support them.

   c. Other considerations or comments.

7. Off the shelf components versus custom components.

B. Maintenance procedures.

1. Who maintains.

    a. Customer's responsibilities.

    b. System supplier's responsibilities.

    c. Subsystem supplier's responsibilities.

    d. Software maintenance and trouble shooting responsibilities.

2. Preventive maintenance routine.

a. Differences by type of system.

3. On-site maintenance.

a. Personnel skills required.

b. First line of action.

c. Second line.

d. Third party maintenance company usage.

4. Off-site maintenance.

   a. Prevalency.

   b. Reasons for.

   c. Trends.

5. Maintenance cost considerations.

   a. T & M versus contract.

b. On-site versus depot.

c. User self-maintenance trends.

C. Documentation (hardware and software).

1. Documentation normally supplied.

a. Levels.

b. Maintenance.

c. Media.

2. Documentation reasonable to expect (by contract and at what cost.)

D. Spare parts inventory management.

1. Standard procedures for determining necessary inventory.

2. Factors that tend to modify standard practices.

3. Packaging.

4. Obsolescence.

5. Alternate sources of parts.

6. Identification and assessment of compatible parts.

7. Spare parts time guarantee.

E. Customer support.

1. Prior to system acceptance.

2. Post-system acceptance.

   a. Type of support.

   b. Level of support.

   c. Active support--how long.

   d. Passive support--how long, type.

   e. How long is reasonable by contract.

F. The dormant state.

1. System preparation procedures.

2. Suitable packaging.

   a. Computer.

   b. I/O equipment.

   c. Lines, cables.

d. Sensors, flowmeters, other measuring devices.

e. Magnetic disks, tape, etc.

f. Paper tape.

g. Documentation.

h. Spare parts.

i. Other system parts.

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3. Environmental considerations.

   a. Temperature.

   b. Humidity.

   c. Atmosphere.

   d. Other.

4. Additional considerations or suggestions.

G. Reactivation.

1. Unpacking procedures.

3. Activation precautions.

a. Sensitive system areas.

4. Failure tracking.

5. Failure reporting.

6. Suggested procedures to prevent repetition.

7. Suggested reactivation frequency.

8. Procedural differences as a function of length of dormant period.

H. Personnel.

1. Skills necessary for system maintenance.

2. Skills necessary for reactivation.

3. Sources of suitable personnel.

4. Trained cadre required for reactivation.

5. Suggested training methods and procedures.

    a. Availability of training materials at novice level.

6. Personnel tracking systems.

II. Future systems.

a. Trends in process control industry.

1. Reliability related.

2. Maintainability related.

3. Personnel/training related.

B. Areas of technological change that will affect:

1. Systems design.

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2. Systems reliability.

3. Systems maintainability.

4. Component reliability.

5. Long-term storage of subsystems and components.

6. Packaging of spares.

7. Parts interchangeability and compatibility.

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8. Diagnostic procedures, techniques and capability.

9 Software production and maintenance.

10. Documentation production and storage.

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C. Suggested maintenance framework for dormant EPD systems.

D. Additional comments and advice.

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